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INFO W18 Fundamentals of Python for Data Science
Nicholas Cerny | Rijul Saxena | Jesus Serna

The Effect of Government Response to COVID-19 on National and Global CO_2 Emissions

Data Sets:

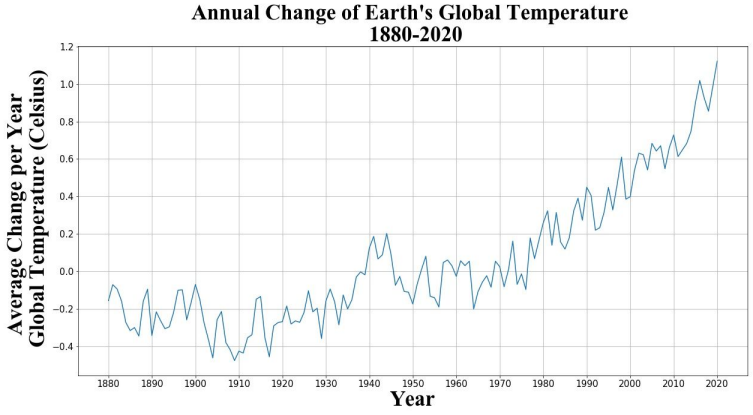
- **Global Temperature Data:** National Aeronautics and Space Administration (NASA)
- **CO2 Emissions Data:** Integrated Carbon Observational System (ICOS)
- **Petroleum Usage Data:** Petroleum and Other Liquids, US Weekly Product Supplied (https://www.eia.gov/dnav/pet/pet_cons_wpsup_k_w.htm)

Introduction:

Earth's climate has naturally fluctuated continually over centuries, producing cycles of hot and cold episodes in our planet's history; however, the introduction of industrial and unfriendly environmental measures has introduced a human metric by which the Earth's climate has rapidly changed.

It has long been understood that the primary cause of global temperature increase is by means of increased Carbon Dioxide, or CO_2 levels in the atmosphere; this is due to the fact that Carbon Dioxide absorbs UV radiation from the Sun that is reflected off of Earth's surface. Increased absorption results in a greater amount of heat remaining in the Earth's atmosphere, thus increasing the Earth's global temperature.

As industries continue to employ environmentally unsafe practices and as executives across the U.S. and the Globe roll back regulations and sanctions against those that damage the environment, the data suggests a drastic increase in the rate of change in global temperature in recent years due to manmade causes. Increased global temperatures has led to severe environmental repercussions, with lasting effects on agricultural, socioeconomic, health, and political stability. [1]



[1] In order to format the above data into a graph that related the annual change to a historical timeline, we elected to average monthly data for each year, creating a data set with columns for the mean and datetime data. Any missing data (of which there were a quite a few entries missing) were changed to NaN using the .replace function. This allowed matplotlib to ignore any missing data, as we basically indicated in our code that NaN's were irrelevant.

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In the early months of 2020, the world encountered its first global health crisis of severe magnitude since the Spanish influenza. Spread by respiratory and droplet contact, the disease caused by the SARS-CoV-2 virus, often referred to as "COVID-19" is extremely contagious and can be fatal, especially for those who are immunocompromised. Naturally, the worldwide response to the global pandemic was to institute necessary and proper health and safety guidelines, including but not limited to:

- limitations on the frequency of gatherings and the number of people who may be allowed to attend them
- social or physical distancing rules, such as a 6 feet (2m) rule of physical separation
- required possession of mask and face shield devices
- enforced stay-at-home or quarantining measures

Questions:

Our team desires to determine whether these policies and the greater COVID-19 crisis have left a tenable and appreciable effect on the state of Earth's climate change. We intend to analyse this by examining the Carbon Dioxide Emissions data courtesy of the Integrated Carbon Global Observation System (ICOS) to determine whether the social policies enacted to delay the spread and harm of the SARS-CoV-2 virus successfully correlates to decreased CO2 emissions in the past six months. Cross-referencing emissions data broken down by professional sector and country, we plan to correlate timelines of COVID public health regulations with a change in emissions progression, thus leading to a potentially delayed or halted global temperature increase. We intend to analyse different countries' approach to the virus, electing to choose countries with varying quantities of people infected with the virus. We then plan to examine other facets of the ICOS data set to determine which sector (currently regulated by quarantine and/or virus regulations) has led to the most significant change in CO2 emissions within the past six months. We plan to supplement our results with national petroleum usage data to further support our findings about whether a change in governmental, socioeconomic, and geopolitical policies has led to a statistically significant change in emissions during the COVID-19 crisis and pandemic. Lastly, we argue that usage of petroleum by fuel type could be a potential indicator of how well a country has followed its COVID-19 mandates.

To summarize, we will investigate the following questions:

- Does an individual countries' CO2 change go in line with its response policies?
- Do countries see a lasting change in CO2 emissions beyond their lockdown periods?
- Nationally, how do virus policies relate to the United States's emissions and economy?
- What can petroleum usage show regarding the US adherence to lockdown policies and is there a link to fluctuations in national emissions?

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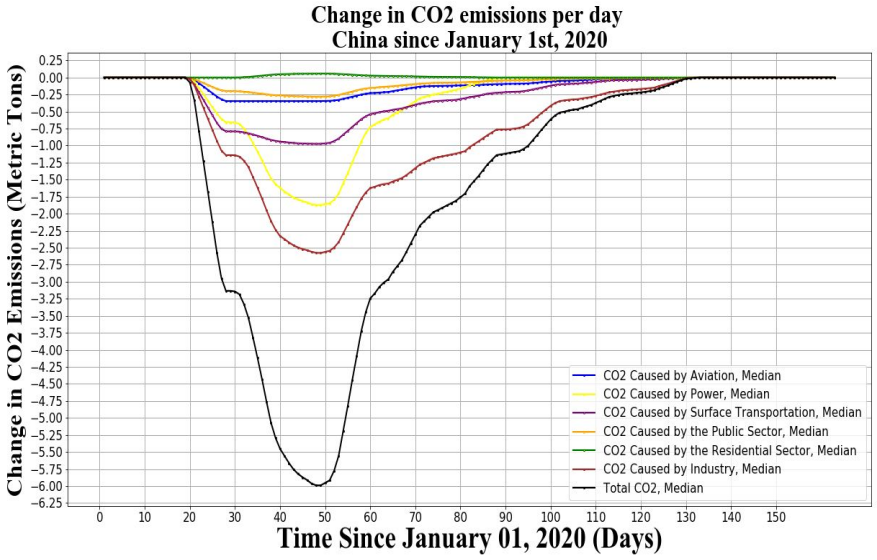
1. International Response

We have elected to analyze ten different countries and their emission rates based on varying levels of viral infection and geographic positioning. The data we are using takes a normalized value for emissions for 2020, based on past emissions data, and measures the deviation from that set normalized value. Thus, any negative value relates to a lower concentration of Carbon Dioxide emission than what would be normally expected; positive values indicate a higher concentration of Carbon Dioxide emissions than would have been expected without COVID-19 mandates; a value of zero implies no net change in emissions.

The following graphs show an initial drop in carbon dioxide emissions (characterized by a steep negative slope). This corresponds to the country's initial stay-at-home order or accompanying policies. In order to keep this research paper concise, we have elected focus only on the most major accompanying policy updates and how they correspond to emissions decline. **However, a supplemental document is included in the same folder as the research paper that goes into greater detail about international policy updates for each of the respective countries.** [2]



China was the epicenter of the initial virus outbreak. Because of this, China was able to respond relatively quickly in late February. They took action safety measures mandatory in all public spaces, meaning they were able to "open up" their country sooner. This caused the emissions of industry and transportation to slowly go back to their "pre-COVID" levels gradually.

[2] Note about Internal Inconsistencies: the breadth and depth of the international emissions data varies significantly between countries. The U.S. and China's Data has a much larger sample size, and thus we see a contoured line with concavity; by contrast, with many countries, the data only provides "set values" over a period time and thus the graph looks largely more trapezoidal and rigid. Any values that were missing in the data were replaced with NaN to avoid issues with averages and further analysis. The data also came in a str format, and thus we had to convert all strings into floats that could be parsed by the computer.

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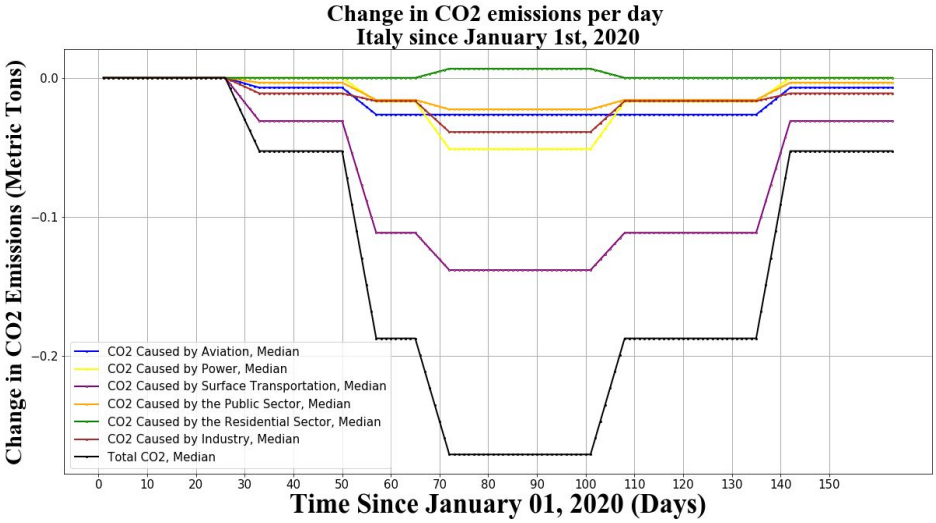
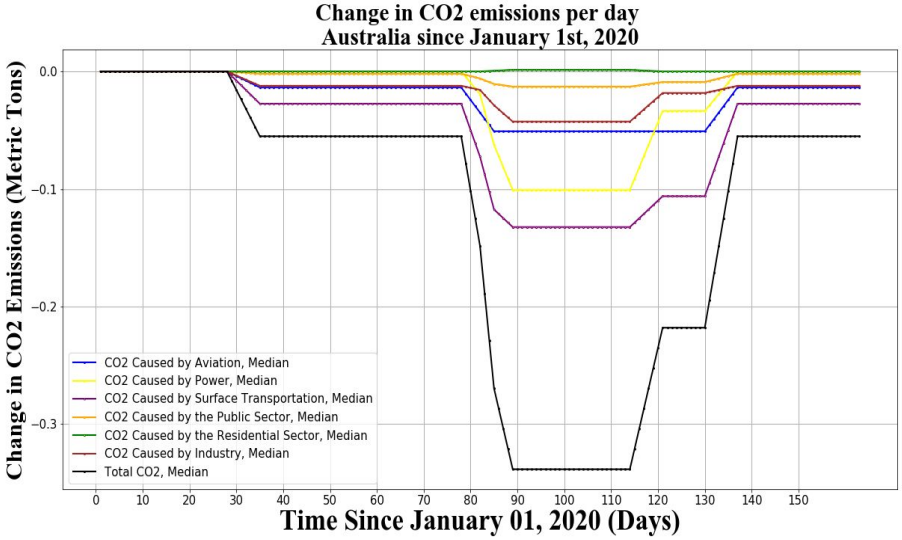
Italy was one of the first countries in Europe to experience widespread COVID infections after China. Emissions begin taking a downward turn near day-27. The graph displays that public transportation significantly impacted CO2 emissions. Italy maintained a larger period of lock-down compared to other countries, spanning over 110 days of total reduced emissions over .5%. Later in the middle of April, Italy decided to begin reopening which corresponds to the day 100-110; thus, as the country began to employ various measures to reopen businesses and travel in order to support its economy, we see a drastic increase in emissions, back towards the normalized value (represented by 0% on the graph above).





Australia closely monitored the progression of the virus from its onset, officially imposing a stay-at-home order and closing establishments in mid March. Their initial national awareness explains the subtle decrease in emissions from day-30 to day-78, after which policies mandated more serious measures causing the downward spike we observe in the graph.

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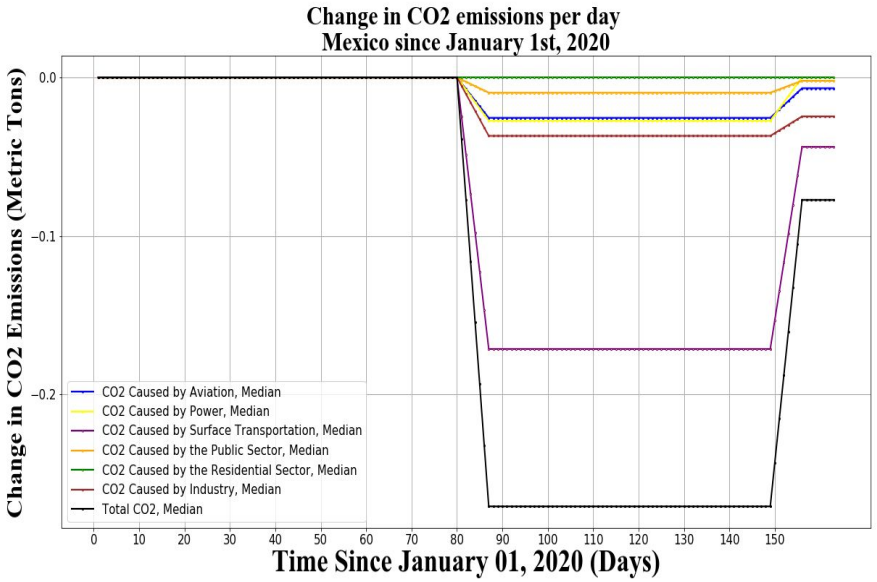
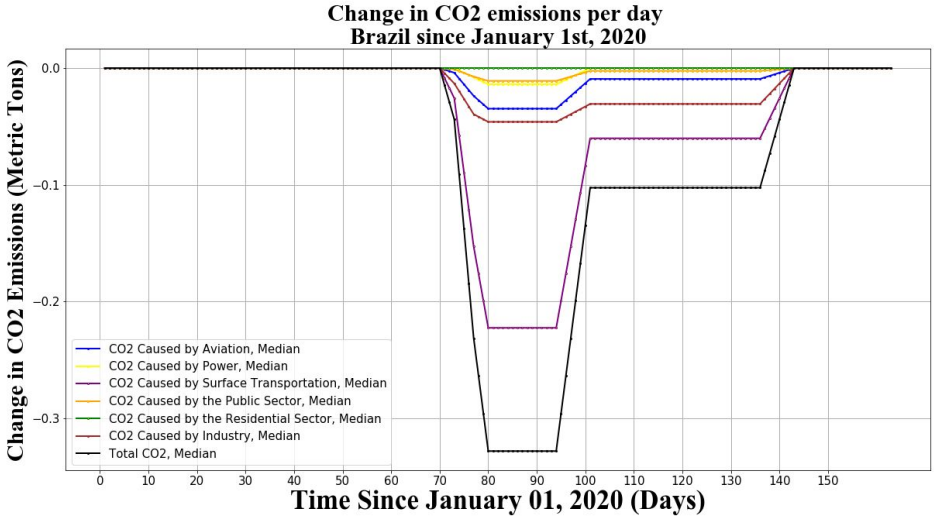
Mexico was not immediately impacted by the COVID-19 disease, which we see with the emission data not changing until day 80. The country began closing high risk gathering spots in late March despite heightened skepticism from locals across the country. Regardless, efforts were still made throughout some months and 'New Normal' policies began taking effect on May 18th. The emissions data collected tells a similar story of reduced emissions from various sectors as other countries; however, it is worth observing the minimal change in residential sector emissions. Less wealthy countries like Mexico and Brazil maintain no net change in residential emissions while more wealthy countries, like the United Kingdom and Italy, have increasing trends in residential energy use.



Brazil

Brazil, with one of the most inadequate responses to the Coronavirus crisis, sees the shortest decline in emissions data over their national crisis. This is largely due to the fact that all quarantine measures were implemented at local county levels, rather than through the federal government, under President Bolsonaro. Bolsonaro is a frequent critic and skeptic of the seriousness of the crisis, and thus the restrictions placed on travel and industry were far less severe than most countries.



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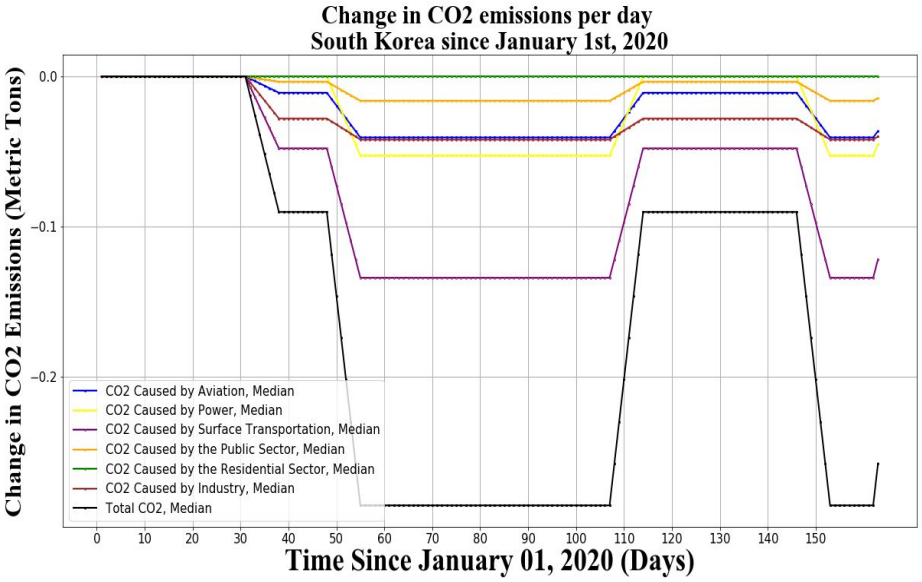
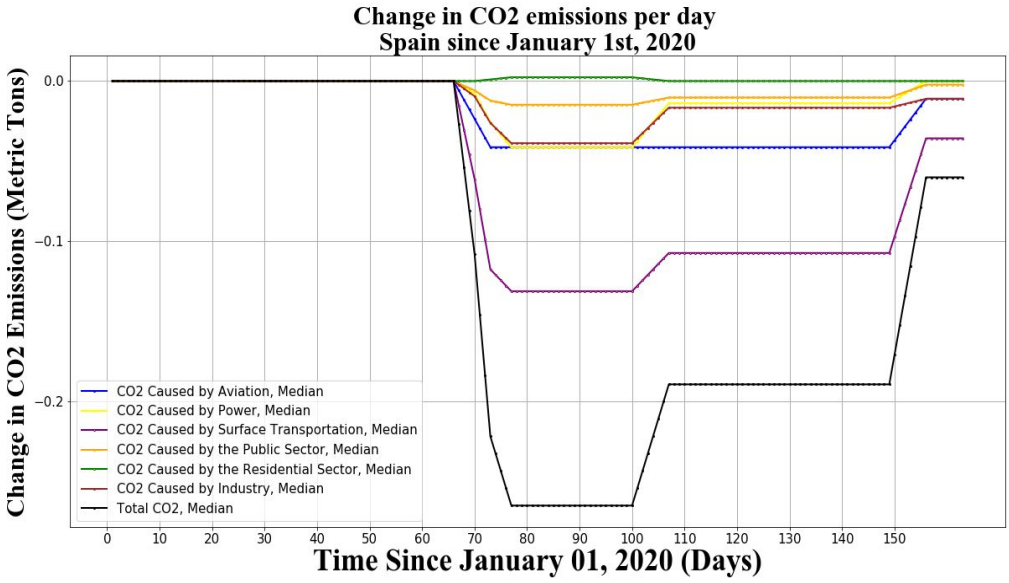
South Korea

South Korea has the most unique graphic visual, as it confirms efforts to retain a second wave of infections in the country given the up and down behavior of emissions. The seriousness in response from South Korea is clear in the rate of change of decrease in emissions, both in the response to the first wave and also the second. Unlike most other countries, South Korea also experienced a large drop in power emissions.





Spain

In mid-March, Spain left all central decisions to their Health Ministry, which ordered all non-essential movement and business to cease. Eventually in late June they began to open up again. This is seen in the data with the two gradual increases in emissions back to their normalized value.

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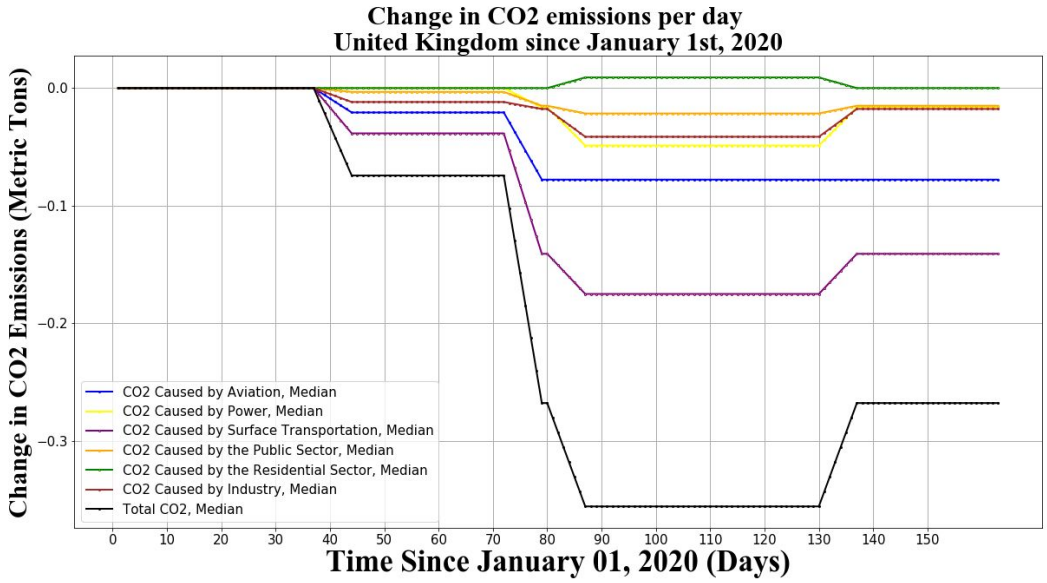
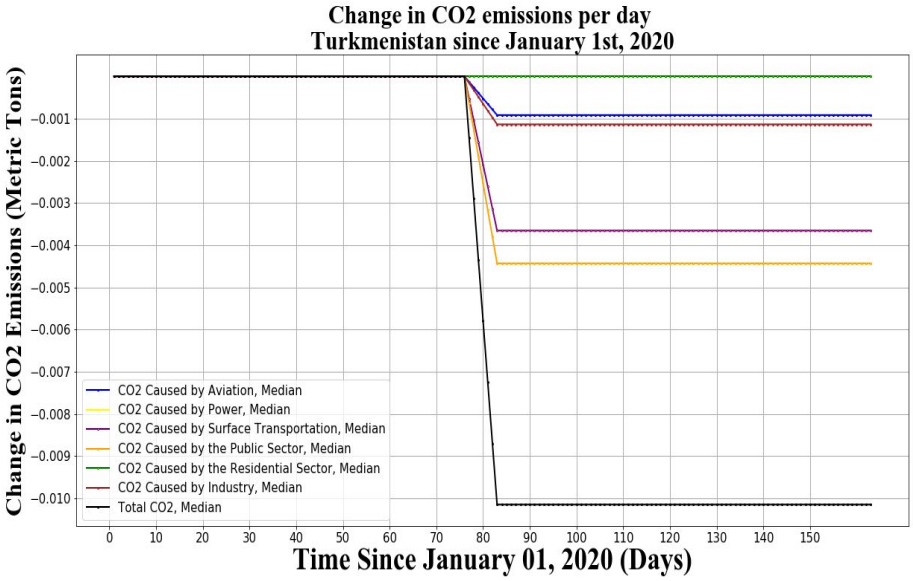
United Kingdom

The United Kingdom not only decreased their overall emissions, they also exhibited an increase in residential emissions, most likely due to strictly enforced quarantines. As the U.K. opened up towards the start of May, however, emissions began to rise back to their normal levels.





Turkmenistan

Turkmenistan did not have as much data as other countries, but also did not report any cases. For that reason, the percentage of emissions decrease is in the order of fractions of a percent. There is suspicion that COVID-19 is spreading unreported, so this data may become obsolete in the future.

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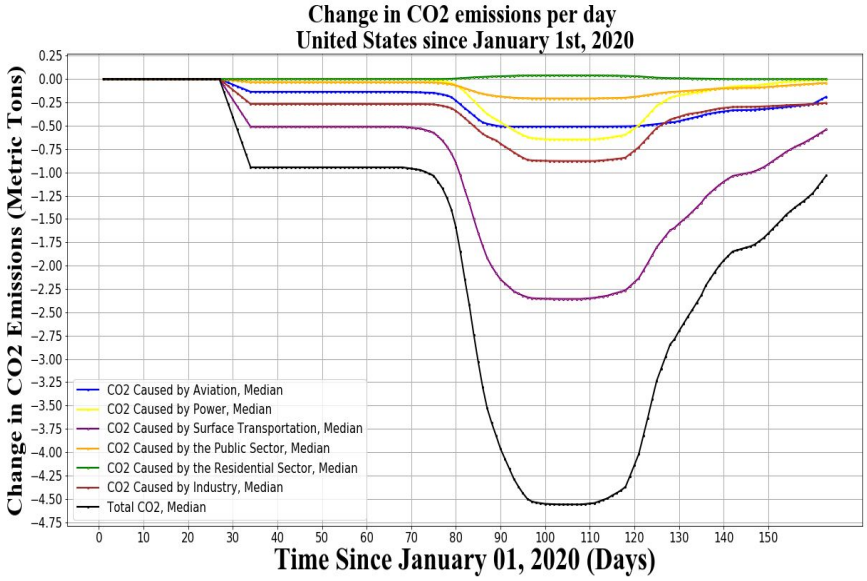
United States:



The United States sees one of the lowest drops in CO2 emissions, decreasing over 4.5% at its maximum rate of change. This is likely due to the relative scale of emissions common in American daily life.

Analysis of the Data in a Greater Context:

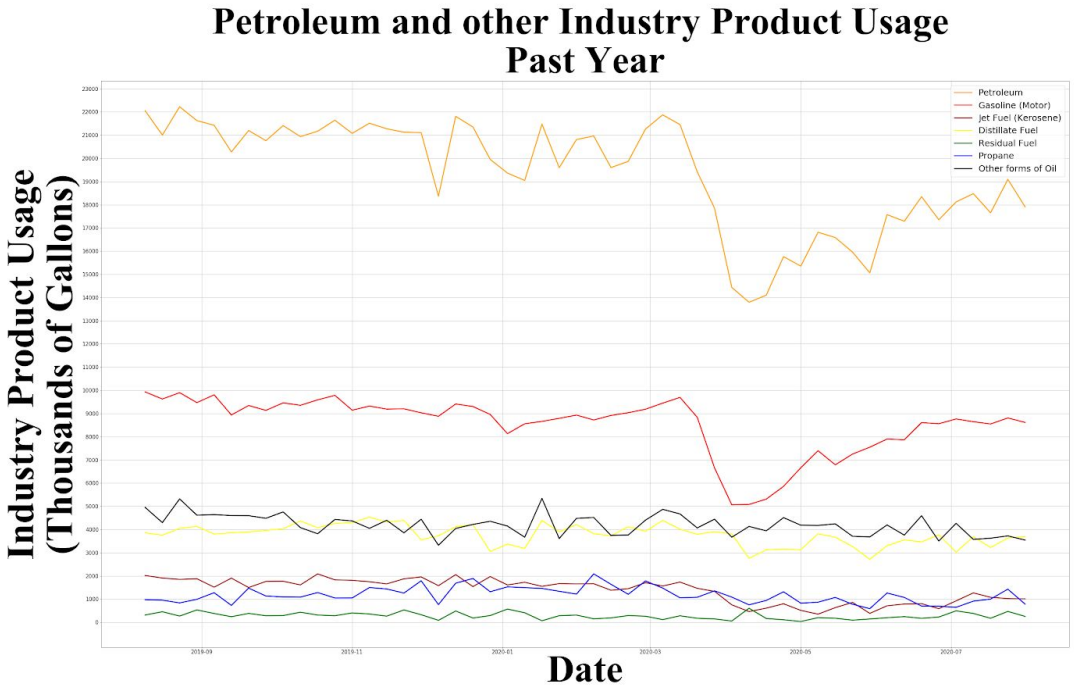
Analysis reveals that, for almost every country we examined, the factor that led to the most significant change in emissions was Surface-Level Transportation, followed by Power and Aviation. We attribute this change largely to the fact that most countries employed quarantine and travel policies curtailing the number of people permitted to travel on a given vehicle and the frequency of trips -- such as flights or trains -- available.

2. **National Perspective -- Petroleum Usage**

As we began to analyze the United States' emissions data, we wanted to take a closer look at exactly what was causing such a steep decline in emissions data; our goal was also to potentially determine if there were any other significant metrics that factored into the steep decline in public and surface transportation emissions. After searching for possible factors, we found an interesting correlation between national petroleum and oil product consumption as our nation faced the unprecedented pandemic.

Seeking to explain the downward spike in US CO2 emissions from the above graph, we took a closer look at key emissions contributors: Transportation, Industry, and Aviation.

Concluding that petroleum usage data by fuel type could provide insight into the operations of these sectors in pre and post COVIDpolicy we include such data below:



Obviously, quarantine and isolation measures factored heavily into the decline in public transportation emissions, but we also found that during the pandemic, the United States's consumption and sale of petroleum and other industrial products significantly decreased. It seems that the United States' stay-at-home response to COVID-19 kept people at home, be it working remotely or self-isolating.. Thus, the amount of surface traffic (cars, busses, etc.) significantly decreased. This was paired with travel restrictions, and together created the significant decrease in petroleum use we see in the data; an increase in the residential sector emissions supports this conclusion.

An anomaly to highlight: not all fuel consumption across the board decreased. We want to point out that distillate fuel (used for trucks) remained relatively stable; we posit that this is due to the high demand for products used to support the COVID economy such as sanitation, food, and medical shipments. This meant that the volume of trucks in business remained static and thus the diesel fuel consumption remained largely unchanged.

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Conclusion:

The Sars-CoV-2 COVID-19 pandemic has been unprecedented in scale, forcing national and global policy-makers to adapt and change their regulations as the situation improves and unfortunately worsens. As we examine both global temperature data, international and national emissions data, and petroleum consumption in the United States of America, our data strongly suggests that various procedures in response to the virus, such as required quarantines, limited freedom to travel, and other national health responses do lead to a categorical decrease in local, national, and global carbon dioxide emissions. However, in each of the following cases, when countries began to return to normalcy, lifting restrictions and regulations, carbon emissions increased, almost completely back to their anticipated and original values.

Thus, the data strongly supports the notion that **this decrease is merely temporary**; the climate situation should still hold significant sway in global policy coming forward. According to the global temperature data compiled by NASA, we are still currently living in a climate crisis: the average increase in temperature (in Degrees Celsius) has reached an all time maximum over the past one-hundred-fifty years. Failure to regulate companies and impose environmental sanctions as punishment will only exacerbate the already serious problem we see today. The general population must begin to take greater action -- to enforce stricter environmental policies at the local level -- in order to create any sort of lasting change in the state of the Earth’s climate.