Climate impact of COVID-19

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Abstract/Scope:

The environmental impact of COVID-19 due to quarantine and economic slowdown has been the reduction of NOx emissions and decreased temperatures in months with mandated shutdown. To detect air quality changes in New York City, US and Wuhan, China we have used satellite images from the Sentinel-5 Precursor mission instrument. For NO2 data analysis we have used the EPA air monitoring tool to download data of daily summaries of NO2 emissions based on location. For temperature data analysis, relating to heat island effect, we used data sets from NOAA weather records from observing stations. Reduction of NOx emissions and heat are correlated with corresponding shutdown months due to COVID-19 precautions.

Introduction:

Beginning in late December 2019 the first cases of COVID-19 were reported in Wuhan, Hubei province, China by March 11th, 2020 the World Health Organization had declared COVID-19 a global pandemic. Government responses in many countries to the COVID-19 pandemic has been mandated quarantine, shelter-in-place, business closure and event cancellation. With millions of people put on lockdown to prevent the transmission of COVID-19, there have been many secondary effects such as environmental, economic, and social impacts. One secondary impact is the reduction of tropospheric pollutants and ground level air pollutants due to lockdown procedures and economic slowdown. Nitrogen Oxide as an air pollutant has seen the most changes in atmospheric levels (Venter, Aunan, Chowdhury, & Lelieveld, 2020). Nitrogen Oxide (NO2) is a fundamental part of Nitrogen Oxides (NOx = NO + NO2). "Nitrogen Oxides are a family of poisonous, highly reactive gases. These gases form when fuel is burned at high temperatures. NOx pollution is emitted by automobiles, trucks and various non-road vehicles (e.g., construction equipment, boats, etc.) as well as industrial sources such as power plants, industrial boilers, cement kilns, and turbines." (U.S. Environmental Protection Agency [EPA], 2019). Based on previous studies Conducted by Nasa Earth Observatory measuring the reduced NO2 emission via satellites, we have chosen two study sites which have been heavily impacted by COVID-19; New York City, United States and Wuhan, China. Because the urban heat island effect is closely linked to air pollution, it is the combination of the heat absorption of metropolitan interface and waste heat from sources such as vehicles and factories, we have also analyzed temperature for corresponding months of COVID-19 lockdown.

March 2020 marked the beginning of COVID-19 procedures. On March 7th, 2020 a state of emergency was declared in New York City followed by the closing of schools statewide on March 16th, and on March 20th all non-essential businesses were closed as well as non-essential gatherings. April was the first full month which New York City was on lockdown

Methods:

Data collection

Sentinel-5P (Ethan, Everett)

In summary, we utilized the Sentinel 5 Offline NO2 image collection to create time lapse graphics that visualized the change in industrial production as a consequence of COVID-19 public health measures.

The Sentinel-5 Precursor is a satellite launched on October 13, 2017 by the European Space Agency to monitor air pollution. The Sentinel-5 Precursor mission collects data useful for assessing air quality, including concentrations of ozone, methane, formaldehyde, aerosol, carbon monoxide, Sulphur dioxide, and Nitrogen oxide (Veefkind, 2012). For our comparison, we chose Nitrogen Oxide emissions. Nitrogen oxides (NO2 and NO) are important trace gases in the Earth's atmosphere, present in both the troposphere and the stratosphere. They enter the atmosphere as a result of anthropogenic activities, such as fossil fuel combustion and biomass burning, and natural processes, such as wildfires, lightning, and microbiological processes in soils (Nitrogen Dioxide (NO2) Pollution, 2019). Because of the restrictions due to COVID-19, we wanted to see how NOx emissions changed in different regions.

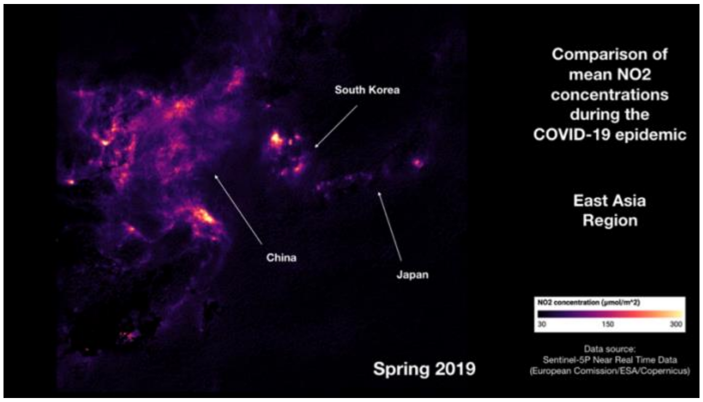
Global NOx emissions can be analyzed and visualized for other purposes and applications. For our research, we used the Sentinel-5P satellite data via Google Earth Engine to visualize the change in industrial productivity around the globe as a result of the COVID-19 pandemic (Vrinceanu, 2020). We began by focusing upon specific areas of interest, such as Eastern China and New York City. We chose these sites as they contained a large, dense population where we would be able to see the most drastic change. Then, we created graphic visualizations of NOx emissions prior to COVID-19 shutdowns in 2019, during the shelter-in-place restrictions in the early spring of 2020, and the re-opening of industry in the late spring of 2020 (Vrinceanu, 2020). Using the Google Earth Engine Code Editor, we could fine tune our visualizations to display our work in a simple, yet significant manner. Our final product includes a time lapse series of NOx emissions in different regions, such as East Asia or the continental United States.

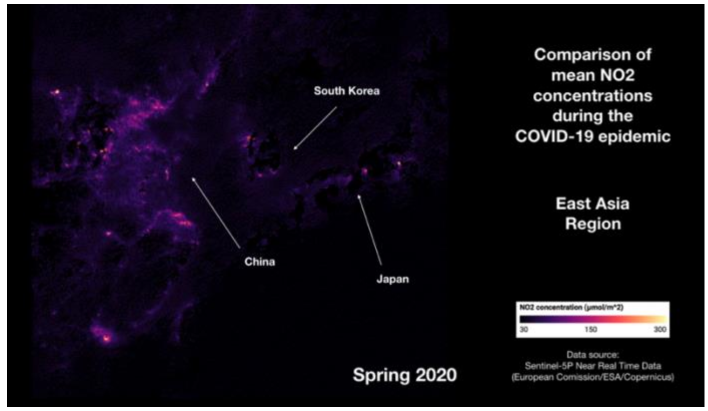
For more information on the process of creating these visualizations using Google Earth Engine, please consult Appendix below.

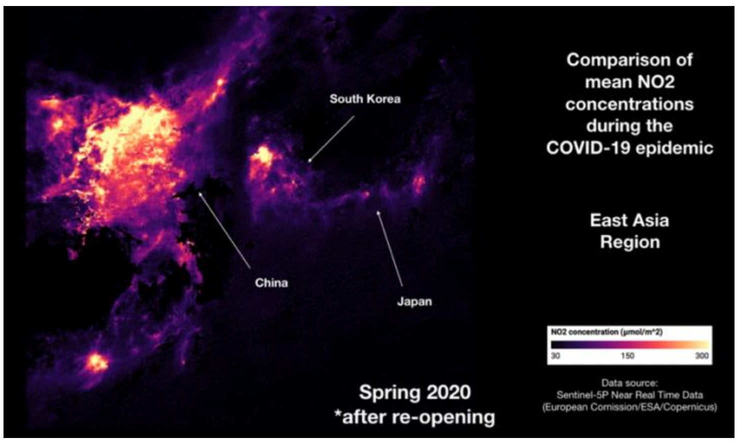
Results:

Below are screenshots from the visualization videos that can be found in our ArcGIS story map. These showcase the drastic changes in NOx concentrations due to the COVID-19 shutdown in various regions of the world.

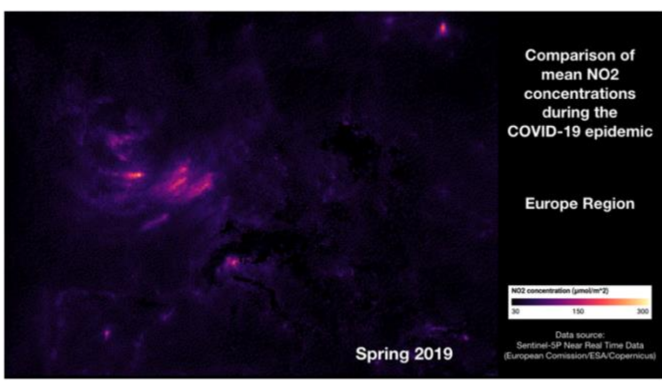
East Asia Region:

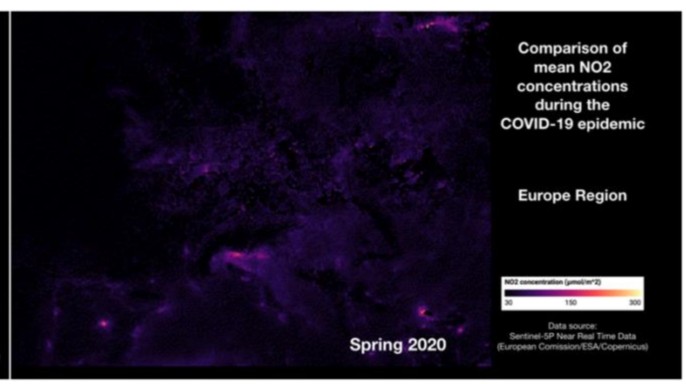






Europe Region:





Appendix:

Our products were scripted and produced within Google Earth Engine Code Editor. We started by setting our dates, selecting data from April 29th, 2019 through April 29th, 2020. This was done to show conditions prior to and the effect of COVID-19 precautions. Sentinel 5P satellite data was imported as an image collection, and from this, a second image collection that would only display data within our selected dates (Sentinel-5P OFFL NO2: Offline Nitrogen Dioxide, 2018). Due to Google Earth Engine constraints, we had to turn our image collection from a single band format to a triple band format. This was completed by using the combine function on our image collection twice, dividing each image by our value maximum (0.0003). The quotient was then multiplied by 255 to translate our collection back into "uint8" format (TomazicM, et. Al, 2019). From here, we adjusted the color pallets and geometry of our site, selecting our area of interest. Finally, we set the parameters of the graphics to export into a .TIFF format. More specifically, we defined the minimum and maximum values, set the geometry to our area of interest, included a visually pleasing palette, defined dimensions to ensure high-quality resolution, and when applicable, frame rate (Google). Once this code was compiled, it was run on the Google Earth Engine servers, and exported to Keynote for post-production work. Below are five steps that can be used by another attempting to replicate our methods.

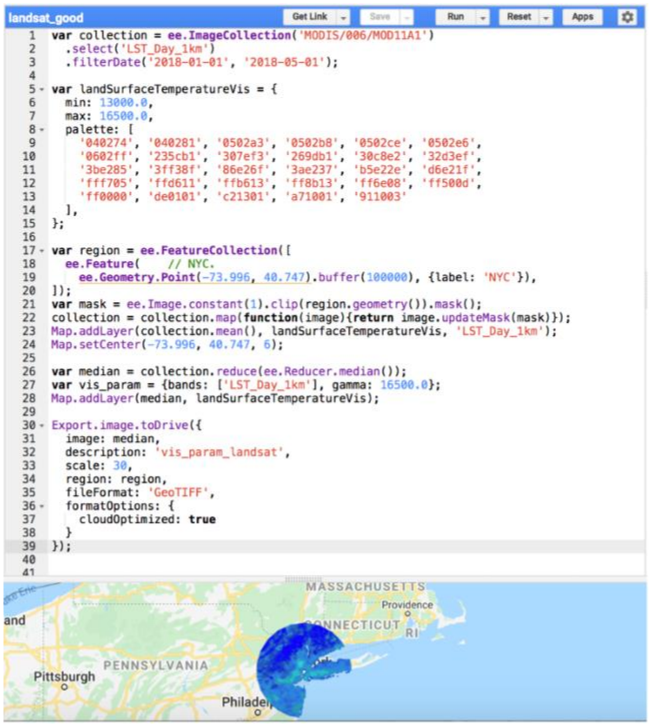
First step - visualize the data

This step was necessary to export the Sentinel 5P satellite data into a .TIFF format, which would later be used by other group members for analysis. To do this, we needed to select the NO2_column_number_density and indicate our selected dates. We visualized the data using the "band_vis" variable, and selected a region using a buffer to encompass the entire area (in this case we covered New York City). We are extracting by our buffer mask and finally export with the correct scale, region, and file format.

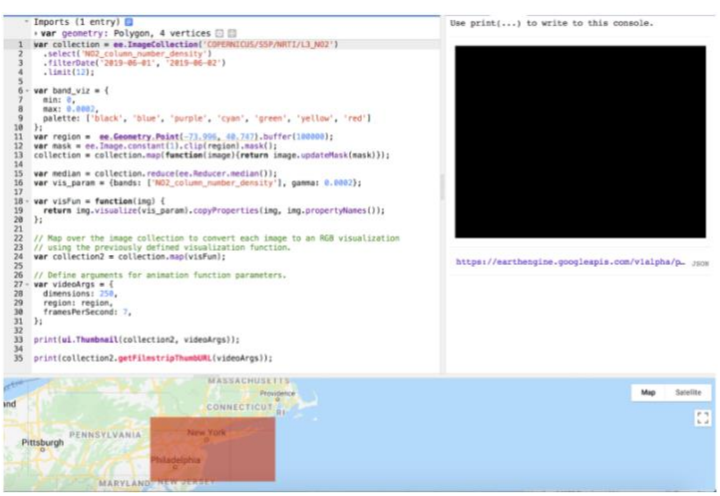
```
var collection = ee.ImageCollection('COPERNICUS/S5P/NRTI/L3_NO2')
  .select('NO2_column_number_density')
  .filterDate('2019-06-01', '2019-06-06');

var band_viz = {
  min: 0,
  max: 0.0002,
  palette: ['black', 'blue', 'purple', 'cyan', 'green', 'yellow', 'red']
};
var region = ee.FeatureCollection([
  ee.Feature(    // NYC.
    ee.Geometry.Point(-73.996, 40.747).buffer(100000), {label: 'NYC'}),
]);
var mask = ee.Image.constant(1).clip(region.geometry()).mask();
collection = collection.map(function(image){return image.updateMask(mask)});
Map.addLayer(collection.mean(), band_viz, 'S5P N02');
Map.setCenter(-73.996, 40.747, 6);

var median = collection.reduce(ee.Reducer.median());
var vis_param = {bands: ['NO2_column_number_density'], gamma: 0.0002};
Map.addLayer(median, band_viz);

Export.image.toDrive({
  image: median,
  description: 'NYC_NO2',
  scale: 30,
  region: region,
  fileFormat: 'GeoTIFF',
  formatOptions: {
    cloudOptimized: true
  }
});
```

Second step - translate the code to other datasets:

After we created the code block to visualize Sentinel 5P NO2 data, we were successfully able to tweak the code to work for other datasets. Below showcases the MODIS Land Surface Temperature dataset that other group members used for their comparisons.



Third step - Running into problems



Although running into problems happened frequently when coding this visualization, we decided to highlight it into a step. In this instance, we kept visualizing a black screen instead of the desired NO2 concentrations. We thought it would be important to show one of the difficulties for future coders attempting this step as a message (you will run into problems; you can overcome it!).

Fourth step - Visualizing the data in a video

The following images show the finished code that successfully gave us animated .GIF visualization within the region of our choice.

Fifth step - Postproduction in Keynote

To add context to the visualization, including title, region, concentration scale bar, credits, and a time reference, the application Keynote was used. To expedite the process, a standard template for all regions was used. To create the time reference that is extremely useful for viewers to understand the visualization, a build order was used. We chose to display seasons, as months or weeks alternated too quickly for viewers to comprehend. With each season, a delay of x seconds was applied to each season matching the x number of frames. This paired up the visualization with the text. Finally, we exported the video and included a before & after screenshot using iMovie to create the finished product.

Citations:

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