The Impact of COVID-19 Shutdown on Particulate Pollution: Analysis of Satellite and Ground Observations

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Abstract

During COVID-19 pandemic in 2020, many cities and areas were shutdown to control the virus spread. The shutdown introduced reduced emissions from vehicles and power plants. In this study, we studied the impact on pollution by analyzing Suomi NPP satellite Visible Infrared Imaging Radiometer Suite (VIIRS) aerosol optical depth (AOD); AOD is a proxy for particulate pollution in the atmosphere. The investigation is performed over several areas and cities around the globe, i.e. China, India, Europe, the United States, New York city, Los Angeles, etc. In general, reductions in AOD compared to the previous years are found in these areas but with some differences. In China, where the pollution in general is high than the other areas, the reduction in AOD is the most obvious. However, in Europe and the United States, the reduction in AOD is less obvious. In India, the effect is in between. Comparing reductions in S5P Tropospheric Ozone Monitoring Instrument (TROPOMI) nitrogen dioxide (NO2) and AOD, we found that they sometimes co-vary and sometimes do not. The possible reason is that NO2 and aerosols do not have the same life time and therefore may not always co-exist at the same time and place. NO2 has a shorter life time and therefore tends to be observed close to the source region. Because of longer life time of aerosols, the aerosols from smoke, dust, and pollution can be transported with long distance and interfere with those from local sources. To tease out the AOD reductions from lockdown compared to business as usual (BAU), AOD data were analyzed using NO2 as a filter. Using this approach we found marginal reductions to particulate pollution in some regions to reductions of up to 20% in other regions. Analysis of particulate pollution in 2020 compared to BAU globally and regionally will be presented.
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Introduction

• COVID-19 related lockdown measures led to a decrease in emissions, specifically from transportation sector due to reduced mobility

➢ We investigated the impact on particulate pollution using Suomi NPP VIIRS aerosol optical depth (AOD)

Disclaimer: trends and seasonality not removed from the data
How to quantify the impact of lockdown measures on AOD changes?

- Most regions that went into lockdown had reduced mobility/traffic emissions, one of the primary source sector for NOx
- Lower AODs in 2020 due to lower emissions but what about the role of transported smoke, dust, and local/regional sulfate aerosols? **How do we extract the signal (reductions in AOD) from anthropogenic emissions changes from natural emissions?**

### Aerosol Sources

<table>
<thead>
<tr>
<th>NO₂</th>
<th>NO₃⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>SO₄²⁻</td>
</tr>
<tr>
<td>VOCs</td>
<td>SOA</td>
</tr>
</tbody>
</table>

**Primary particulates**
- Transported smoke
- Transported dust

<table>
<thead>
<tr>
<th>Approach 1</th>
<th>Approach 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstrated that AOD and NO₂ are correlated and if they correlate well assumption is that source sector is the same*</td>
<td></td>
</tr>
<tr>
<td>• Background NO₂ is 12 µmoles/m²</td>
<td>• Background NO₂ is 12 µmoles/m²</td>
</tr>
<tr>
<td>• High NO₂ and high AOD implies urban/industrial pollution</td>
<td>• NO₂ and AOD co-increase or co-decrease if source sector is the same</td>
</tr>
<tr>
<td>• Low NO₂ and high AOD implies source is transported aerosol</td>
<td>• Filter:</td>
</tr>
<tr>
<td>• Filter: NO₂/AOD &gt; 200</td>
<td></td>
</tr>
</tbody>
</table>

* Wei et al. poster [A005-0026 Correlating Economic Activity Indicators and Tropospheric Column Nitrogen Dioxide during COVID-19 Pandemic in the United States](https://example.com)
As China’s shutdown continued in March, transport of aerosols (smoke) from Vietnam, Cambodia, northern India dominated in Southern China (left panel).

Tropospheric NO$_2$ column shows very little pollution in southern China; no local emissions (middle panel).

Doing NO$_2$/AOD ratio helps isolating aerosols locally generated vs. transported (right panel).
Approach 2 to filter AOD using NO$_2$

Use NO$_2$ to filter AOD data
- NO$_2$ > 12 µmoles/m$^2$
- $\Delta$NO$_2$ > 5 µmoles/m$^2$ with criteria that both AOD and NO$_2$ should either co-increase or co-decrease

Capture AOD changes when source sector for aerosols/aerosol precursors and NO$_2$ are the same
Impact of COVID-19 Lockdown Measures on AOD

Changes in AOD significant and have implications for developing abatement strategies in polluted regions.
COVID-19 Lockdown Impact: VIIRS AOD Change in US

14% decrease

Reductions in Surface PM2.5 (2020-2019)

- 50.00%
- 0.00%
- 50.00%
- 100.00%
- 150.00%

Feb  Mar  Apr

Washington DC  Chicago  Los Angeles

Used another filter used NO$_2$/AOD ratio (>400)
Conclusions

• Investigated methods to filter AOD using NO$_2$ data to tease out aerosol signal from urban/industrial sources
  ➢ Refining thresholds to find a better solution
  ➢ Need to remove seasonality and trends in data

• Reductions in AOD are observed over polluted areas in China, India, and western Europe due to COVID-19 lockdown measures
  ➢ In CONUS, AODs are low and no significant reduction of AOD is observed. These results are in agreement with findings from other researchers

We started with a 12 µmoles/m$^2$ for background NO$_2$ in our work. Our analysis shows it varies by season and region.