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

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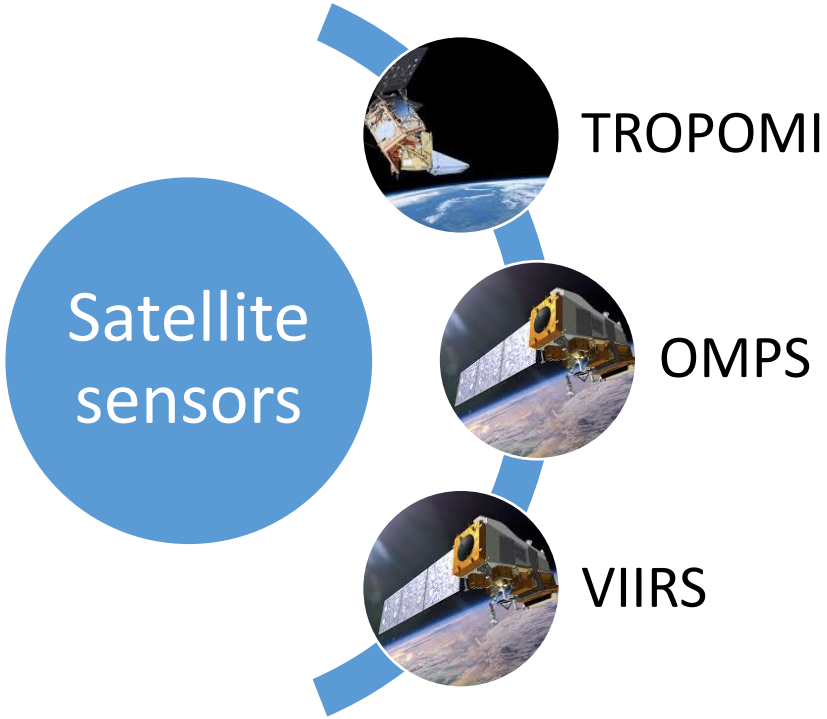
Abstract

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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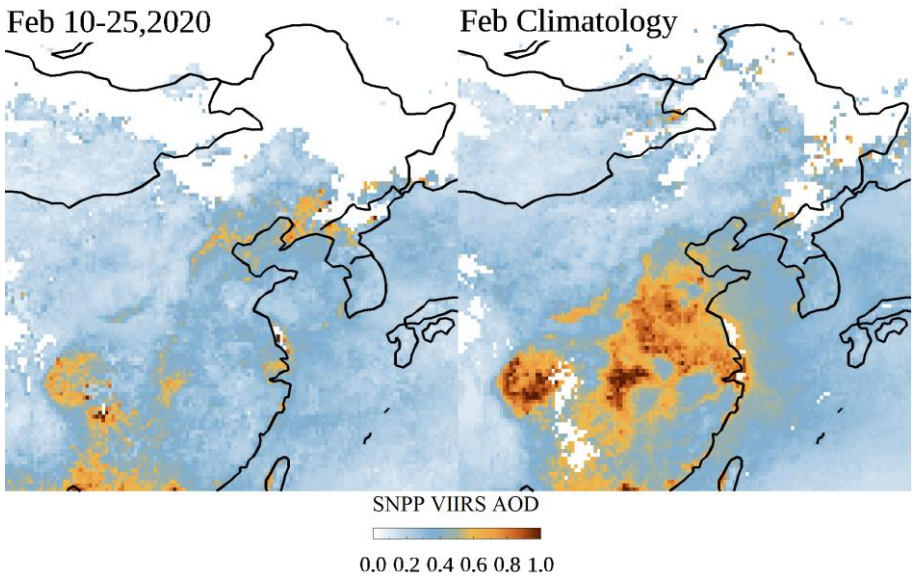
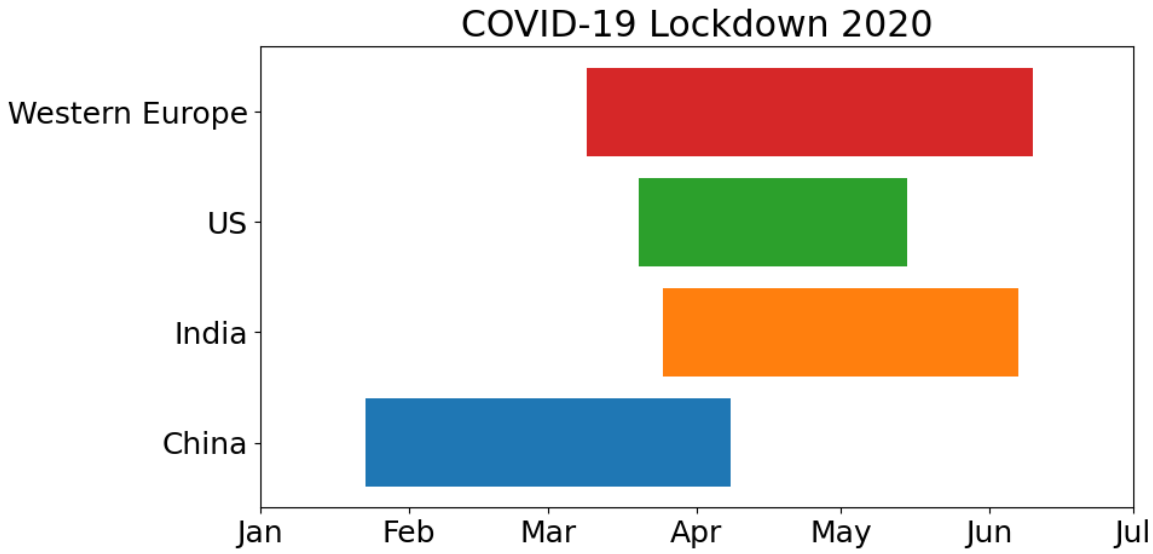
Introduction

- 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)





Source: Wikipedia

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?**

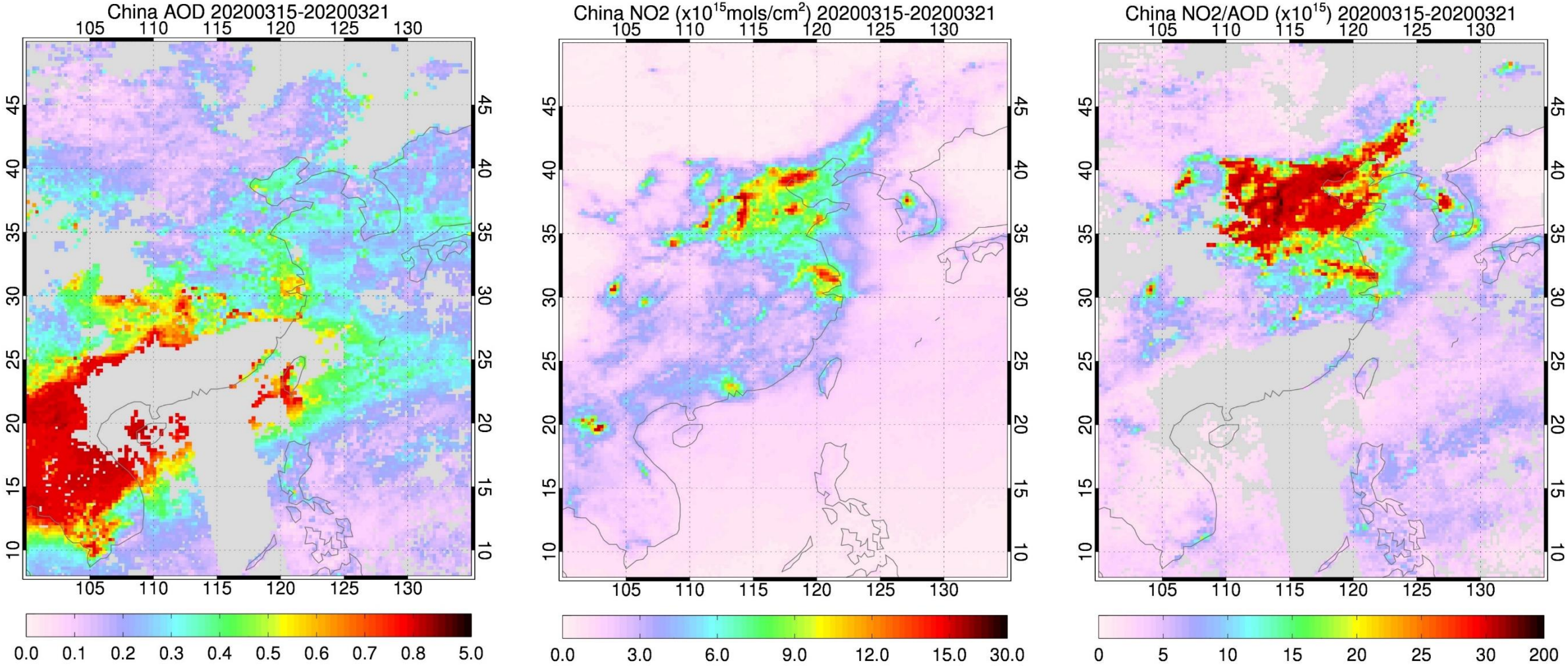
Aerosol Sources

NO_2	→	NO_3^-
SO_2	→	SO_4^{2-}
VOCs	→	SOA
		Primary particulates
		Transported smoke
		Transported dust

Approach 1	Approach 2
Demonstrated that AOD and NO_2 are correlated and if they correlate well assumption is that source sector is the same*	
• Background NO_2 is 12 µmoles/m^2	• Background NO_2 is 12 µmoles/m^2
• High NO2 and high AOD implies urban/industrial pollution	• NO2 and AOD co-increase or co-decrease if source sector is the same
• Low NO2 and high AOD implies source is transported aerosol	• Filter: |ΔNO2| > 5 µmoles/m^2 and AOD increases or decreases in the same direction
• Filter: NO_2/AOD > 200	

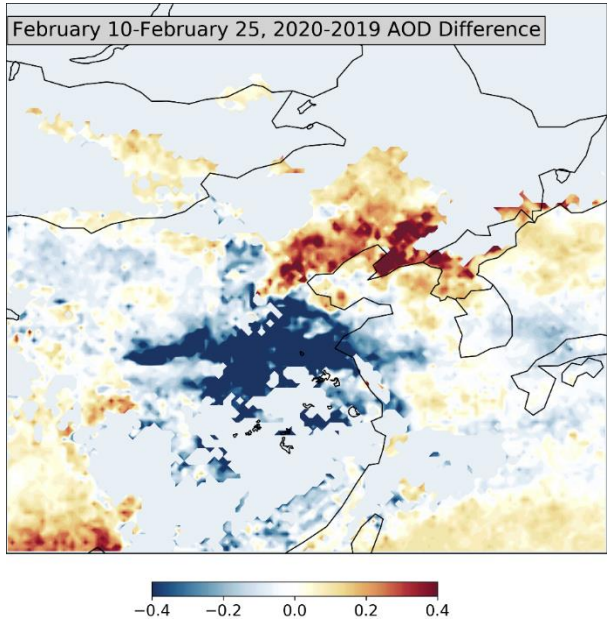
* Wei et al. poster A005-0026 Correlating Economic Activity Indicators and Tropospheric Column Nitrogen Dioxide during COVID-19 Pandemic in the United States

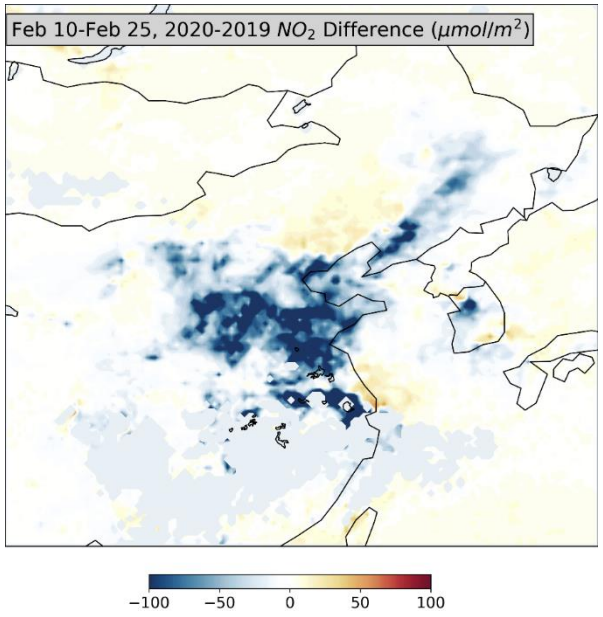
Approach 1 to filter AOD using NO_2



- 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



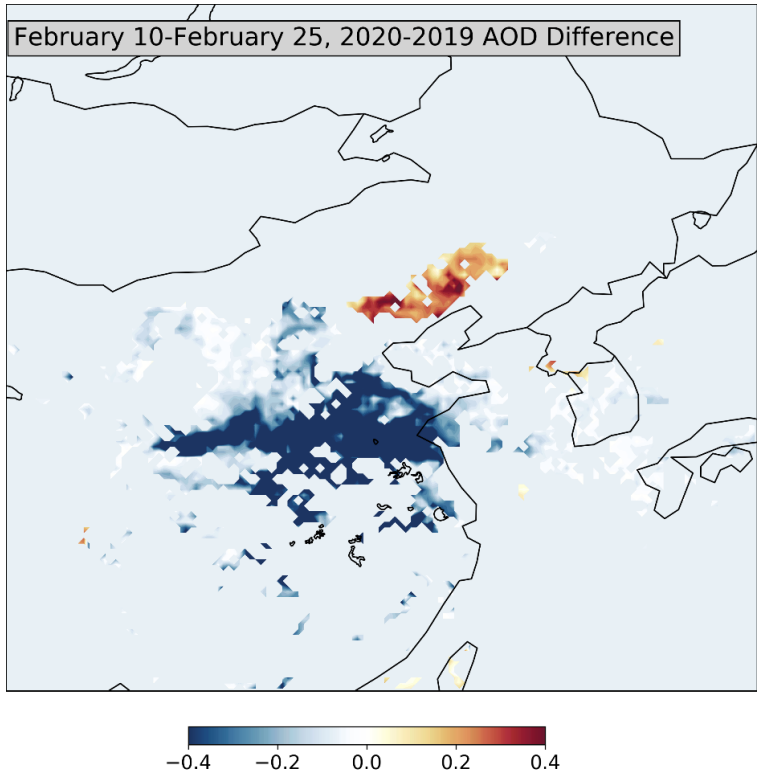


Use NO_2 to filter AOD data

- NO_2 > 12 µmoles/m^2
- ΔNO_2 > 5 µmoles/m^2 with criteria that both AOD and NO_2 should either co-increase or co-decrease

Filtered

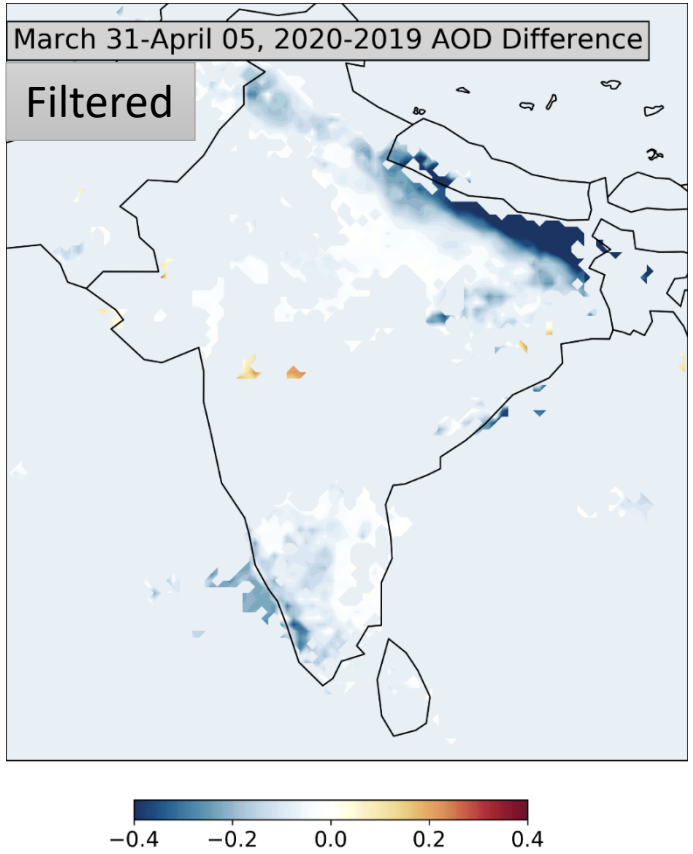
41% decrease



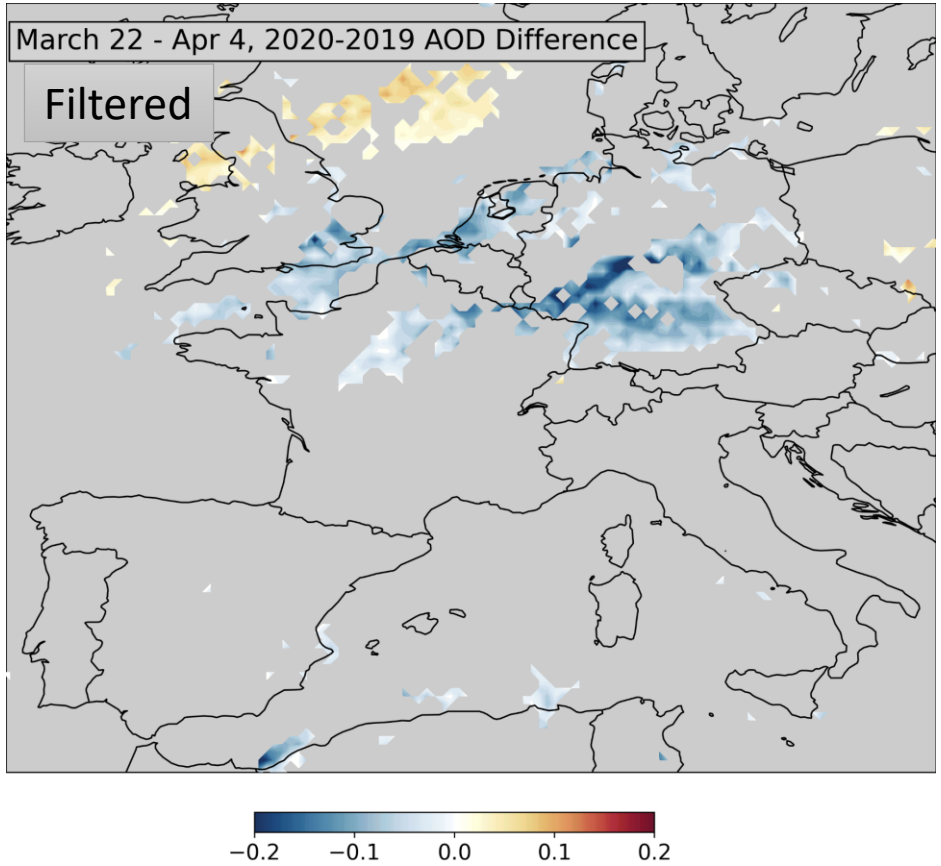
Capture AOD changes when source sector for aerosols/aerosol precursors and NO_2 are the same

Impact of COVID-19 Lockdown Measures on AOD

35% decrease



20% decrease

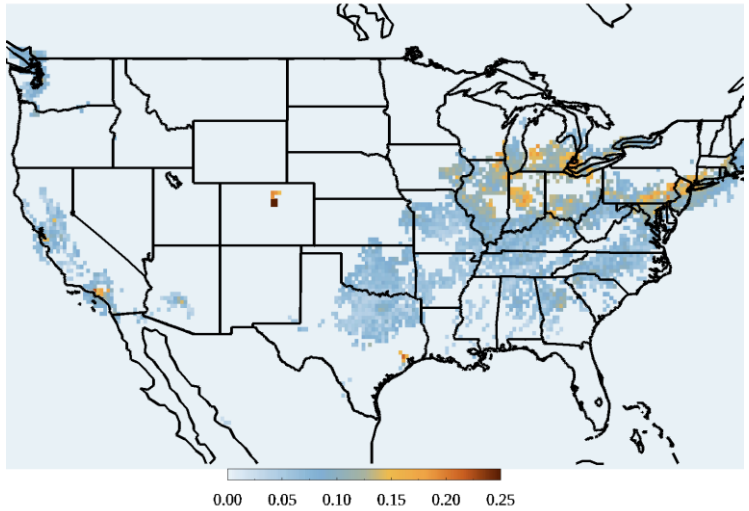


Changes in AOD significant and have implications for developing abatement strategies in polluted regions

COVID-19 Lockdown Impact: VIIRS AOD Change in US

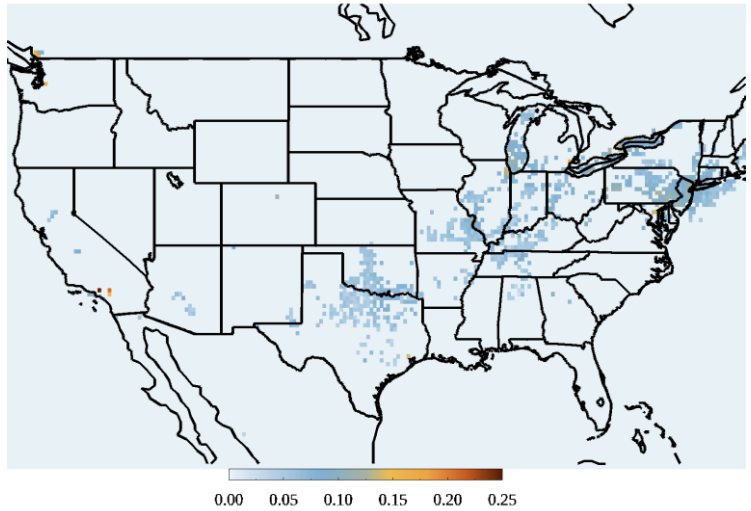
SNPP VIIRS AOD

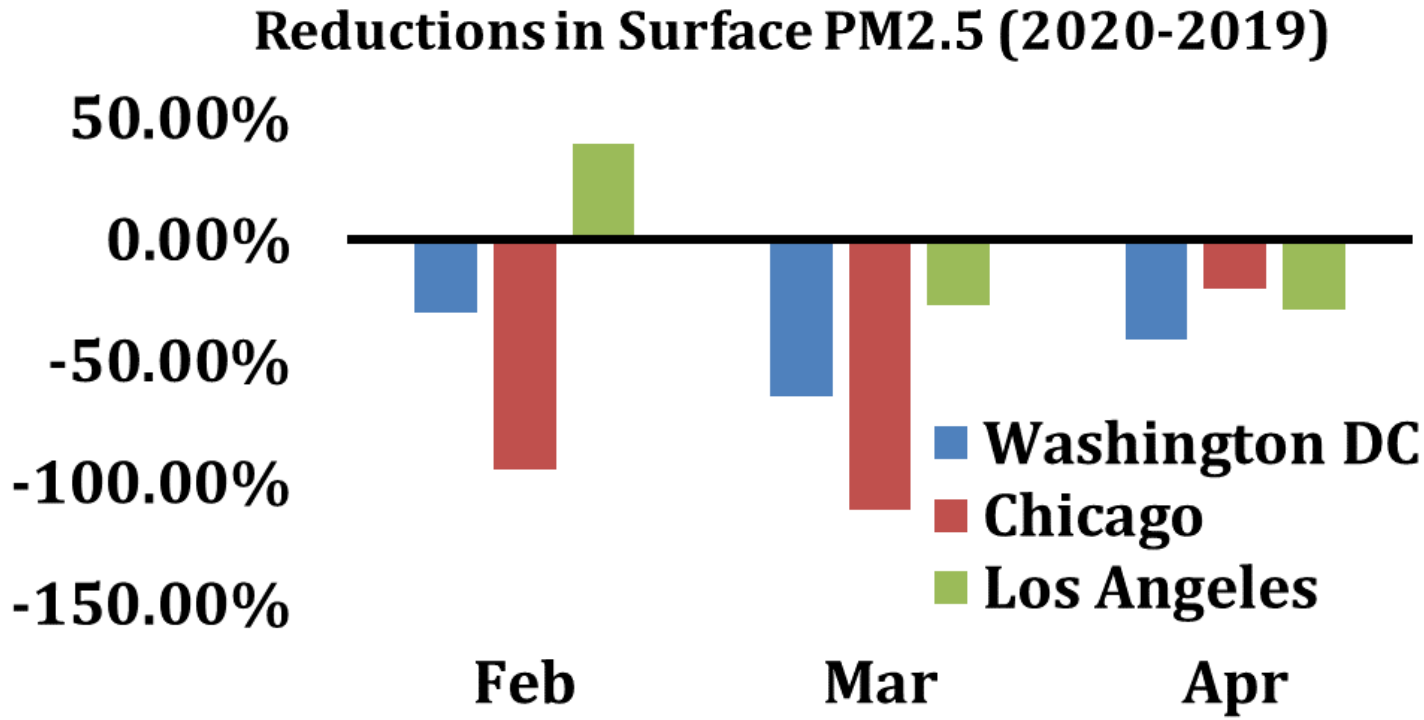
March 01-31,2019



14% decrease

March 01-31,2020

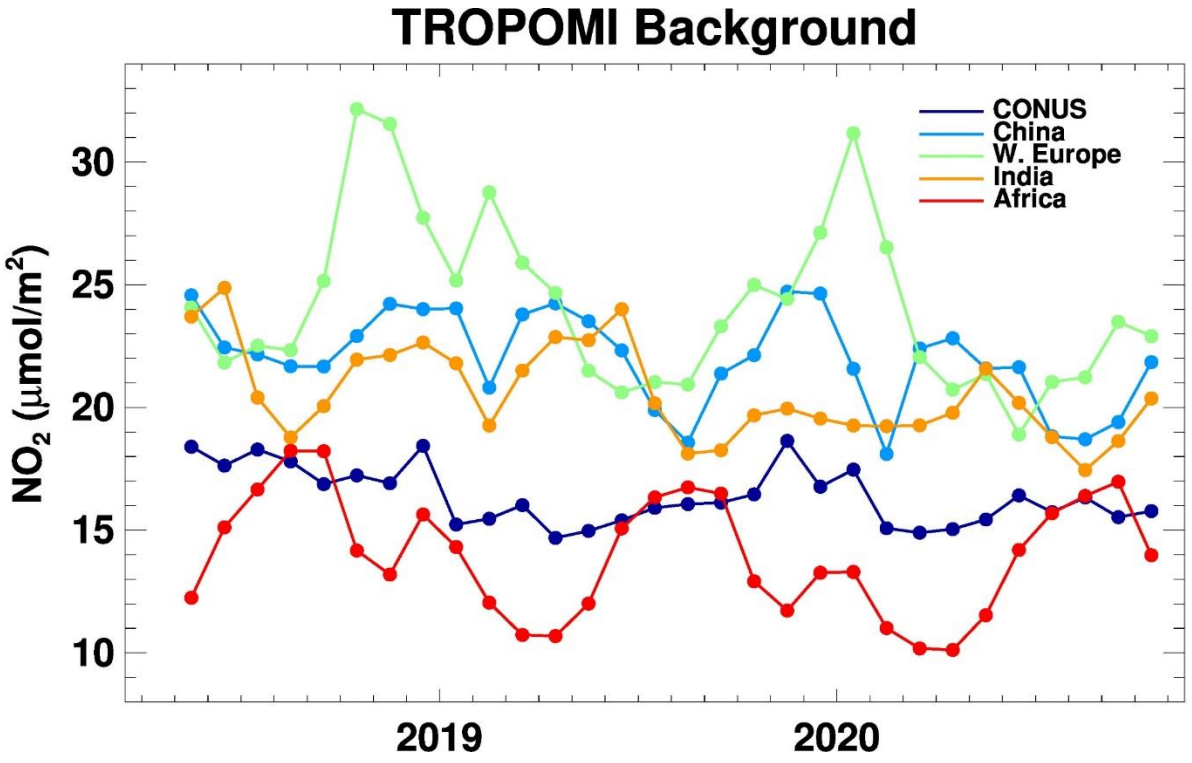




Used another filter used NO_2/AOD ratio (>400)

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.