Urban and Fire Emissions Effects on Ozone in the Troposphere

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Introduction

Tropospheric ozone is important for local and global air quality. Tropospheric ozone is a pollutant that can cause health issues if present in high concentrations. Ozone is a climate forcing, ranking third after CO₂ and CH₄ in radiative forcing. This means an increase or decrease in the amount of ozone in an area could lead to substantial changes in the local climate due to the change in radiative forcing. It is produced from the reaction of Volatile Organic Compounds (VOCs) with Nitrogen Oxides (NOₓ). Sources of ozone precursors are mainly anthropogenic and biomass burning (BB) emissions (Bourgess et al. 2020).

The Atmospheric Tomography (ATom) project, consisting of four seasonal deployments from August 4th to May 23rd, 2018, was an airborne mission that involved the NASA DC-8 flying along a global circuit (North to South over the Pacific Ocean, then South to North over the Atlantic Ocean). The DC-8 was equipped with scientific equipment used to measure a large range of atmospheric compounds and parameters, including altitude, latitude, longitude, dichloromethane (CH₂Cl₂), tetrachloroethylene (C₂Cl₄), acetonitrile (CH₃CN), hydrogen cyanide (HCN), and ozone (O₃) among other atmospheric species and parameters. The DC-8 took off from San Francisco, California. From there it proceeded to fly in the remote troposphere along a global circuit (North to South over the Pacific Ocean, then South to North over the Atlantic Ocean). Locations of interest for this study include San Francisco, California, Ascension Island, the northeastern African coast, and the northern Atlantic Ocean. The NASA DC-8 landed back in San Francisco on August 31st, 2018. The DC-8 was then deployed again three times more from January 26th 2017 to February 22nd 2017, September 28th 2017 to October 25th 2017, April 26th 2018 to May 23rd 2018.

Results

• Measured O₃ near the coast of Africa was plotted on a scatterplot against each of the emission tracers. Only plots with a strong correlation between O₃ and an emission tracer were kept. The same method was applied at all four locations. A trendline was plotted on the graphs and the R² value was calculated to determine how closely O₃ correlated to the trend. These trends were compared to determine which compound O₃ is most closely correlated with. The main source of O₃ at these locations can thus be identified.

Discussion

HCN consistently had a positive correlation with ozone at each location chosen (fig. 1-4). It did not matter if the location is mostly influenced by fire emissions like Ascension Island (fig. 3) or a location with high urban emissions and fire emissions like San Francisco (fig. 1). These lead to the idea that fire emissions have a higher influence on the amount of ozone in those locations. The R² values of the HCN graphs (fig. 1-4) are all higher than the R² values for the CH₂Cl₂ graphs (fig. 5-8). This further suggests fire emissions are influencing the amount of ozone more than urban emissions.

CH₂Cl₂ did not have a consistent correlation with ozone. Ascension Island even had a negative correlation with ozone. The R² value in each graph is also consistently lower than Hydrogen Cyanide.

Conclusion

• By knowing fire emissions have a greater influence on ozone than urban emissions policies can be made that help reduce ozone or keep ozone at a steady amount. This has two major consequences.
  • First, it can help improve air quality by reducing the ozone in the air.
  • Second, it can help delay these changes in climate by keeping the radiative forcing steady or even slightly decreasing it if needed. This will lead to increases in human health and the environment’s health.
• More research is still needed to prove fire emissions are the main influencer of ozone levels on a global scale, but this project has provided the first steps needed to answering that question.

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References


Methods

• The data was collected from the ATom project. This project started on August 4th, 2016. The NASA DC-8 was equipped with scientific equipment used to monitor altitude, latitude, longitude, dichloromethane (CH₂Cl₂), tetrachloroethylene (C₂Cl₄), acetonitrile (CH₃CN), hydrogen cyanide (HCN), and ozone (O₃), among other atmospheric species and parameters. The DC-8 took off from San Francisco, California. From there it proceeded to fly in the remote troposphere along a global circuit (North to South over the Pacific Ocean, then South to North over the Atlantic Ocean). Locations of interest for this study include San Francisco, California, Ascension Island, the northeastern African coast, and the northern Atlantic Ocean. The NASA DC-8 landed back in San Francisco on August 31st, 2018. The DC-8 was then deployed again three times more from January 26th 2017 to February 22nd 2017, September 28th 2017 to October 25th 2017, April 26th 2018 to May 23rd 2018.

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• CH₂Cl₂ and CH₃CN are atmospheric tracers of BB emissions. These tracers can be used to determine the respective influence of urban and BB emissions for each sampled air mass during ATom.

• ATM data can help create an understanding of how O₃ is being influenced by fire and urban emissions at specific locations in the remote troposphere. This information can lead to further discoveries that could show what is the major source of ozone in the troposphere. The current understanding is that urban emissions dominate O₃ globally. However, more focus has recently been put on fire emissions and how these emissions impact the global O₃ budget. An outstanding question is: Are fire emissions a more significant source of tropospheric ozone than urban emissions?