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 concentration. Ozone is a climate forcer, ranking third after CO_2 and CH_4 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 (NO_x). Sources of ozone precursors are mainly anthropogenic and biomass burning (BB) emissions (Bourgeois et al. 2020).

•The Atmospheric Tomography (ATom) project, consisting of four seasonal deployments from August 4th, 2016 to May 23rd, 2018, was an airborne mission that involved the NASA DC-8 flying in the remote troposphere 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 (CH¬2Cl¬2), tetrachloroethylene (C¬2Cl$_4$), acetonitrile (CH_3CN), hydrogen cyanide (HCN), and ozone (O_3).

•CH_2Cl_2 and C_2Cl_4 are atmospheric tracer of urban emissions, and CH_3CN and HCN are atmospheric tracers of BB emissions. These tracers can be used to determine the respective influence of urban and BB emissions is for each sampled air mass during ATom.

•ATom dataset can help create an understanding of how O_3 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 O_3 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?

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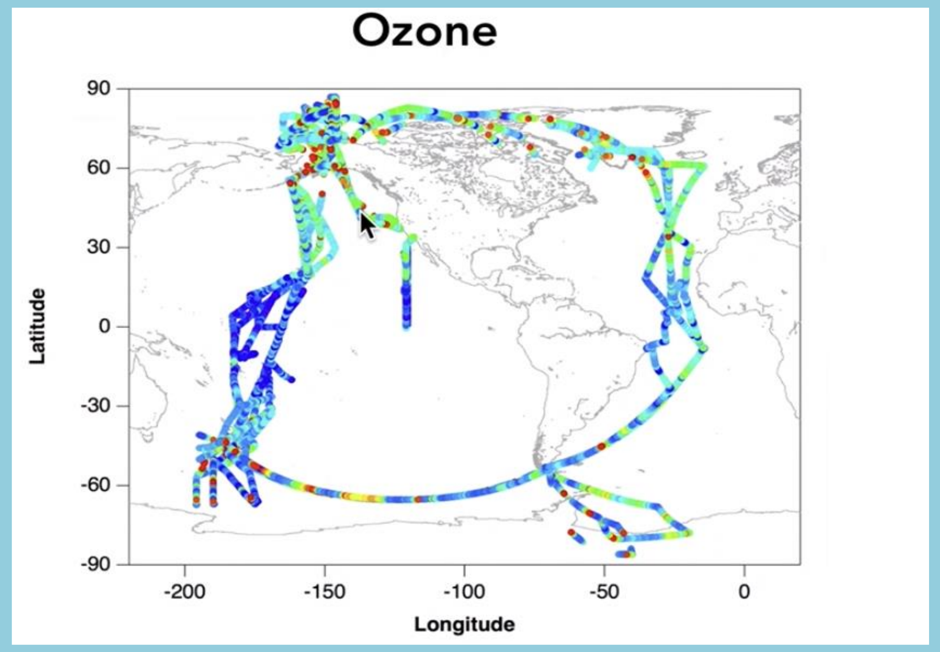
Methods

•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 (CH_2Cl_2), tetrachloroethylene (C_2Cl_4), acetonitrile (CH_3CN), hydrogen cyanide (HCN), and ozone (O_3), 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 northwestern African coast, and the northern Atlantic Ocean. The NASA DC-8 landed back in San Francisco on August 31st, 2016. The DC-8 was then deployed again three more times from January 26th, 2017 to February 22nd, 2017; September 28th, 2017 to October 25th; and 2017, April 26th, 2018 to May 23rd, 2018.

•Measured O_3 near the coast of Africa was plotted on a scatterplot against each of the emission tracers. Only plots with a strong correlation between O_3 and an emission tracer were kept. The same method was applied at all four locations. A trendline was plotted on the graphs and the R^2 value was calculated to determine how closely O_3 correlated to the trend. These trends were compared to determine which compound O_3 is most closely correlated with. The main source of O_3 at these locations can thus be identified.



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Results

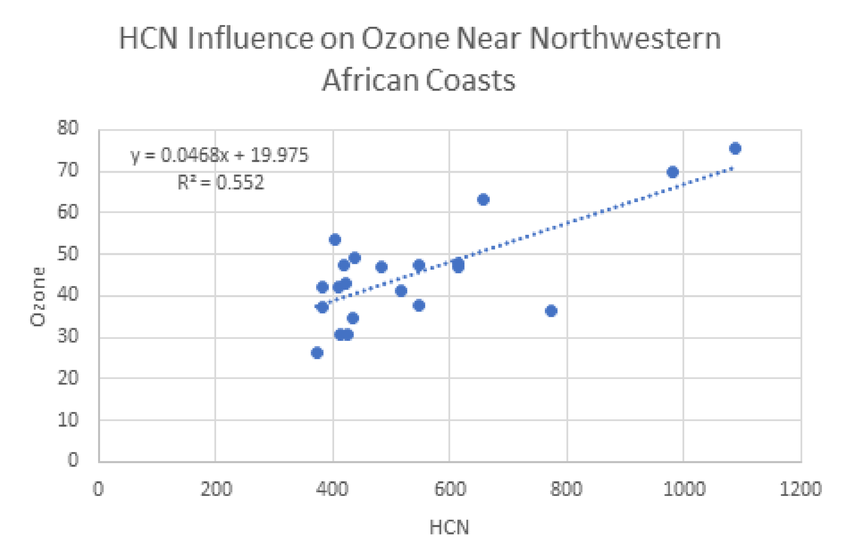


Figure 1: Hydrogen Cyanide Influence on Ozone Near Northwestern African

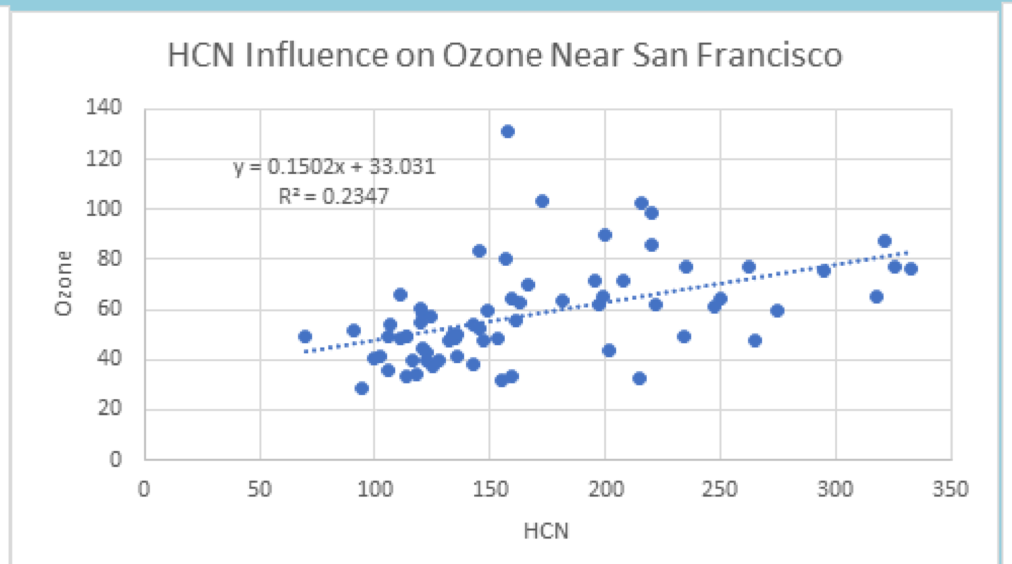


Figure 2: Hydrogen Cyanide Influence on Ozone Near San Francisco

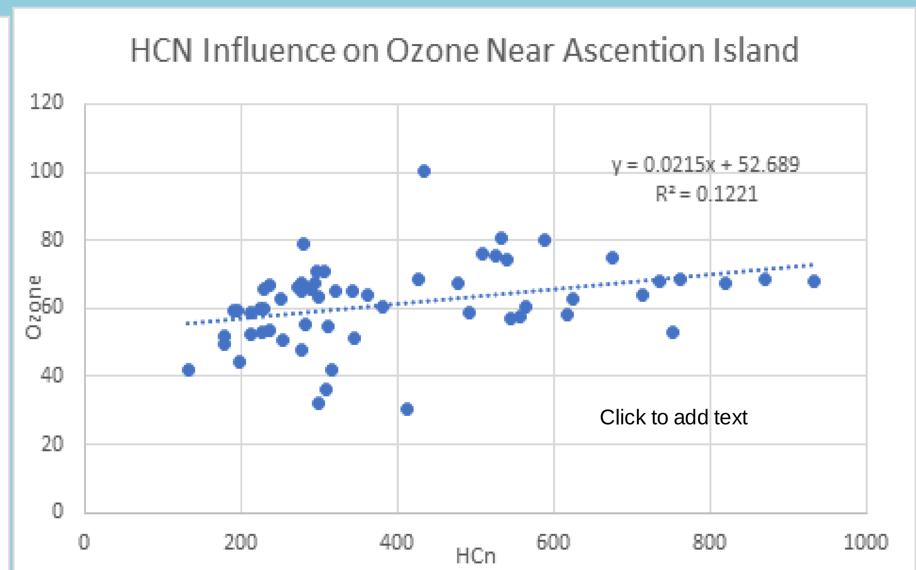


Figure 3: Hydrogen Cyanide Influence on Ozone Near Ascension Island.

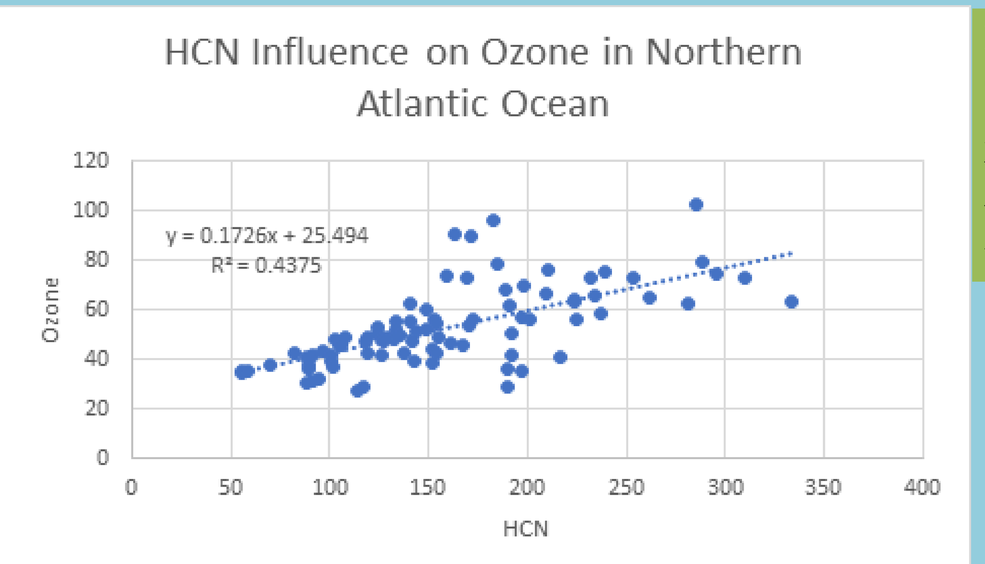


Figure 4: Hydrogen Cyanide Influence on Ozone in Northern Atlantic Ocean

Hydrogen Cyanide consistently has a positive correlation with Ozone. All R^2 values are greater than .01

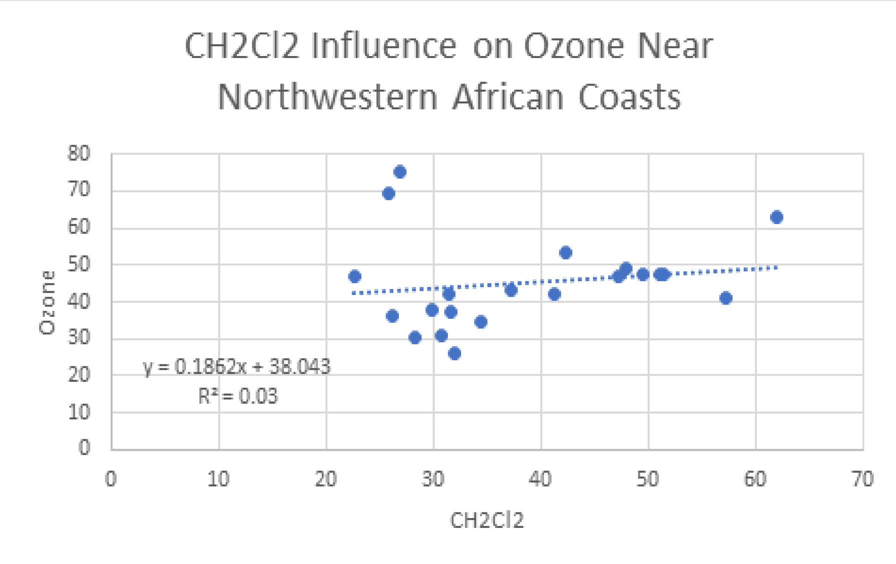


Figure 5: Dichloromethane Influence on Ozone Near Northwestern African Coasts

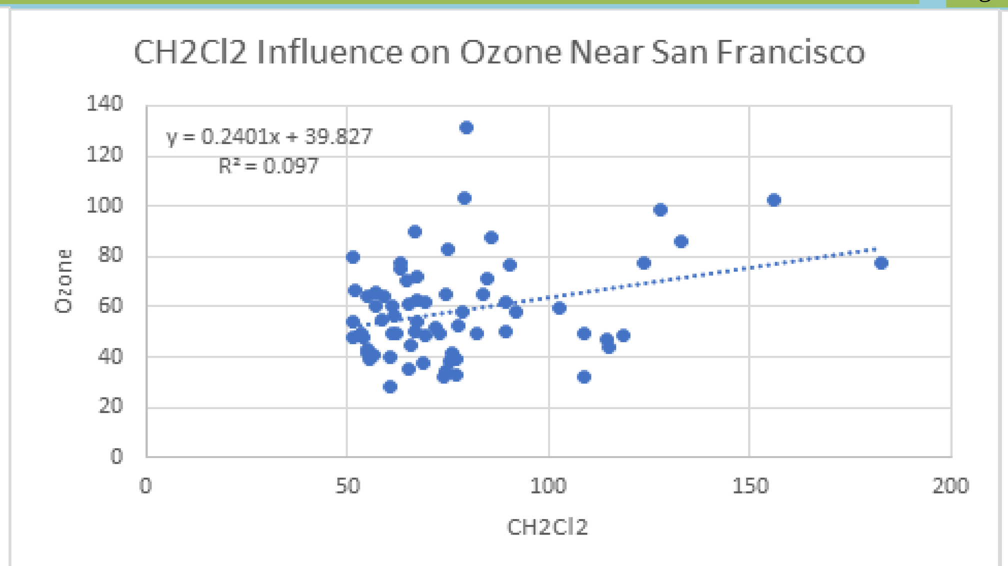


Figure 6: Dichloromethane Influence on Ozone Near San Francisco, California

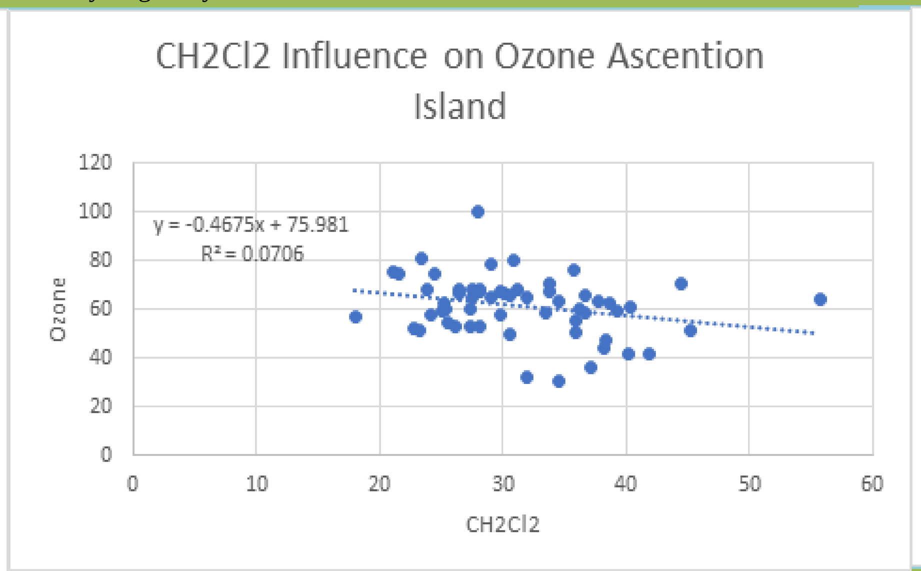


Figure 7: Dichloromethane Influence on Ozone Near Ascension Island

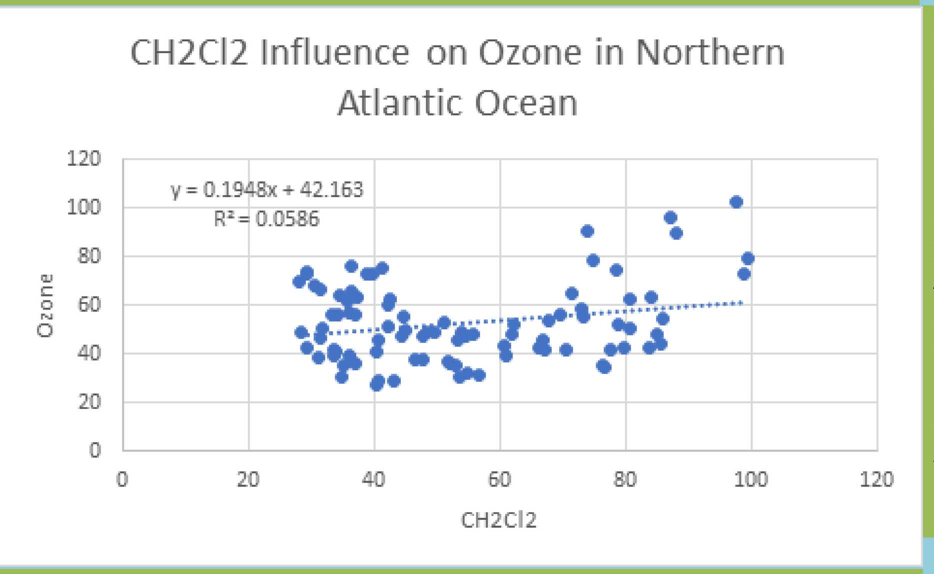
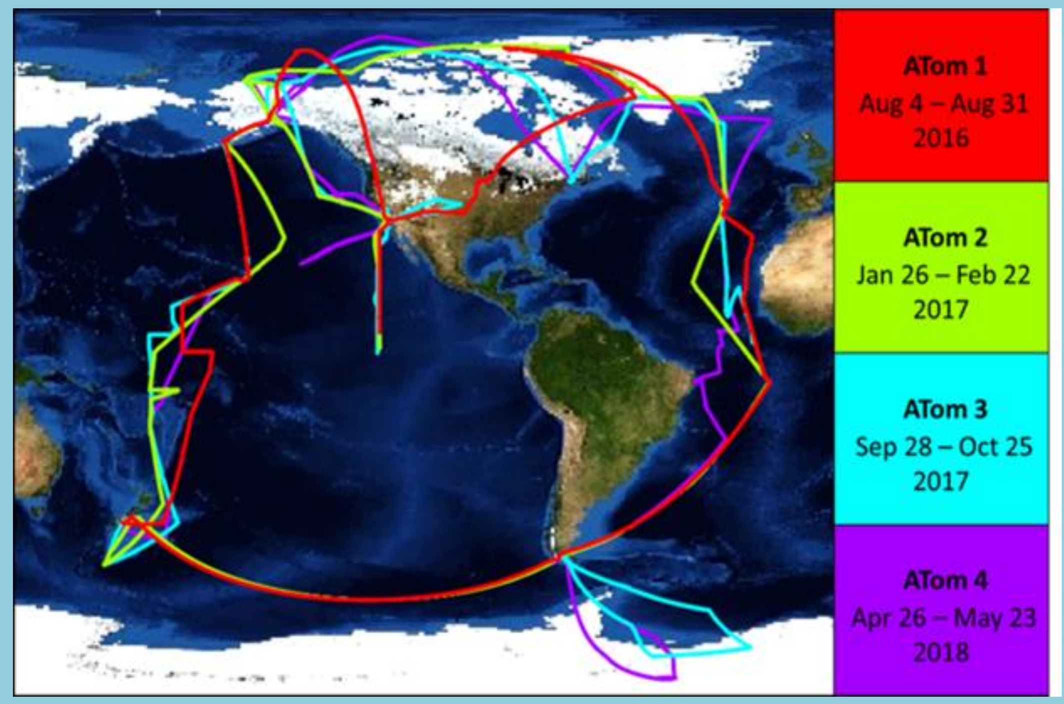


Figure 8: Dichloromethane Influence on Ozone in Northern Atlantic Ocean

CH_2Cl_2 did not have a consistent correlation with ozone. Ascension Island even had a negative correlation with ozone. The R^2 value in each graph is also consistently lower than Hydrogen Cyanide.



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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. 2). These leads to the idea that fire emissions have a high influence on the amount of ozone in those locations. The R^2 values of the HCN graphs (fig. 1-4) are all higher than the R^2 values for the CH_2Cl_2 graphs (fig. 5-8). This further suggests fire emissions are influencing the amount of ozone more than urban emissions.

•CH_2Cl_2 did not have a consistent correlation with ozone (fig. 5-8). CH_2Cl_2 near Ascension Island had a negative correlation with ozone (fig. 7). This poses a new question: can urban emissions decrease the amount of ozone in the atmosphere.

one. By examining the wind patterns more precise data can be produced by knowing where the emissions and ozone were produced originally.

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 reduce 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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Acknowledgements

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References

Bourgeois, I. et al. (2020). Global-scale distribution of ozone in the remote troposphere from ATom and HIPPO airborne field missions. *Atmospheric Chemistry and Physics Discussions*, pg. 3.https://doi.org/10.5194/acp-2020-315