Deriving Wildfire CO Emissions from TROPOMI Satellite Observations
Professor Kimberly Strong and Tyler Wizenberg
2022 Summer Project Description

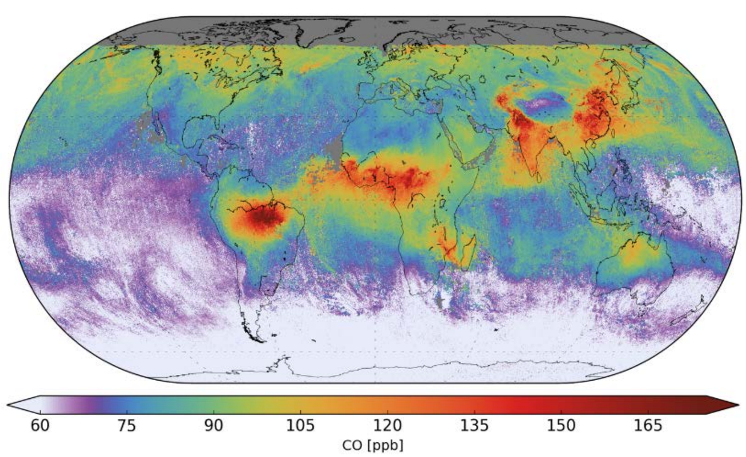
Research Area

Our research involves the use UV-visible and Fourier transform infrared spectrometers to measure the concentrations of trace gases in the atmosphere. We use atmospheric remote sounding measurements from ground-based and satellite instruments for studies of ozone chemistry, climate, and air quality. Understanding of the physical and chemical processes underlying these issues requires accurate and timely observations of atmospheric composition.

Research Topic

Currently, there are two primary methods through which the trace gas emissions of wildfires can be estimated, the 'bottom-up' approach, and the 'top-down' approach. The bottom-up method uses satellite measurements of fire radiative power and/or burned area along with prescribed emission factors (i.e., the amount of a pollutant emitted per kg of dry biomass combusted) to approximate the total emissions of the fire. However, significant uncertainties exist when estimating wildfire emissions via a bottom-up approach, mostly resulting from large uncertainties associated with emission factors, which are typically determined in a laboratory setting. For carbon monoxide (CO), the uncertainty associated with the emission factor for boreal forests is approximately 35%, and for ammonia (NH_3) it is as high as 85%. By using a top-down approach and directly estimating biomass burning emissions with satellite trace gas observations, tighter constraints can be placed on wildfire emissions, and the reliance on emission factors is no longer required.

The project will use a top-down method first applied to NO_2 data from the Ozone Monitoring Instrument (OMI) in Mebust et al. (2011) that allowed for the direct estimation of emission coefficients of wildfires over several land types in Nevada and California. Adams et al. (2019) extended the analysis beyond OMI NO_2 measurements to include observations of CO and NH_3 by the Infrared Atmospheric Sounding Interferometer (IASI) instruments and the Cross-track Infrared Sounder (CrIS). By using the 2016 Fort McMurray fires as a case study, they were able to obtain direct emission estimates, as well as the lifetimes of species within the smoke plume and derived emission ratios.



TROPOMI CO total column mixing ratio averaged from November 13-19, 2017. The data show clearly CO enhancements by wildfires in Brazil, Africa, Madagascar, and Australia as well as anthropogenic air pollution in India and China. Image from http://www.tropomi.eu/data-products/carbon-monoxide based on Borsdorff et al. (2018).

In comparison to OMI and the IASI instruments, the newer TROpospheric Monitoring Instrument (TROPOMI) has a very high spatial resolution (7 × 7 km^2 prior to August 6, 2019, and 7 × 5.6 km^2 afterwards), which can provide an increased ability to resolve wildfire plumes. Furthermore, TROPOMI includes an aerosol layer height product which may be used to directly evaluate biomass burning plume heights, preventing a reliance on models or other sensors. Plume shape and height was quoted as a notable source of uncertainty in the analysis in Adams et al. (2019).

In this project, you will be using data from the cutting-edge TROPOMI satellite instrument, combined with meteorological data from the European Centre for Medium-range Weather Forecasts ERA-5 model, to directly derive estimates of CO wildfire emissions. The methods will first be tested on smaller wildfires, and once confidence has been gained in the approach, it can be applied to larger wildfires such as the 2019 California fires. The derived emissions estimates can then be compared against those from the widely used ECMWF Global Fire Assimilation System, which are computed via a bottom-up approach.

Requirements

Applicants should have completed second year or higher, have an interest in atmospheric physics, and have experience with computer programming and data analysis.

For More Information

For more information, contact Kimberly Strong (strong@atmosp.physics.utoronto.ca) and visit:

- Kimberly Strong's Home Page
- Earth, Atmospheric, and Planetary Physics Group
- Department of Physics
- University of Toronto
- NSERC Summer Student Program in Physics at Toronto
- Centre for Global Change Science Summer Undergraduate Intern Programme at Toronto
- TROPOMI

References

Adams, C., Mclinden, C. A., Shephard, M. W., Dickson, N., Dammers, E., Chen, J., ... Krotkov, N. A. (2019). Satellite-derived emissions of carbon monoxide, ammonia, and nitrogen dioxide from the 2016 Horse River wildfire in the Fort McMurray area. Atmospheric Chemistry and Physics, 19(4), 2577–2599. https://doi.org/10.5194/acp-19-2577-2019

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Mebust, A. K., Russell, A. R., Hudman, R. C., Valin, L. C., & Cohen, R. C. (2011). Characterization of wildfire NOx emissions using MODIS fire radiative power and OMI tropospheric NO_2 columns. Atmospheric Chemistry and Physics, 11(12), 5839–5851. https://doi.org/10.5194/acp-11-5839-2011