Solar Absorption and Open-Path FTIR Measurements of 2025 Wildfire Smoke over Toronto

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Motivation

In 2025, Canada experienced its second-worst fire season on record in terms of hectares burnt and impacts on air quality[1]. Previous studies have shown that smoke plumes can be transported thousands of kilometers away [2,3].

Biomass burning has had a significant effect on air quality in Toronto (Canada's most populous city) [4]. The use of ground-based data with a long time series will help assess whether the altered seasonal cycle of CO and other gases emitted by wildfires represents an emerging trend from increasingly severe fire seasons.

Instrumentation

The University of Toronto Atmospheric Observatory (TAO) (43.66°N, 79.40°W, 174 m) ABB Bomem DA8 FTIR Spectrometer records mid-infrared solar absorption spectra, as part of NDACC. Of the 16 currently retrieved trace gases, fire-related species include CO, C_2H_6, CH_3OH, H_2CO, HCN, HCOOH and NH_3.

The UofT Bruker 125M Open-Path Fourier Transform Infrared Spectrometer (OP-FTIR) is colocated with the TAO FTIR at the McLennan Physical Labs in Toronto and measures over a total pathlength of 300m. Measurements are independent of sunlight and are made continuously. Currently, the primary fire-related species retrieved with the OP-FTIR is CO.

Results

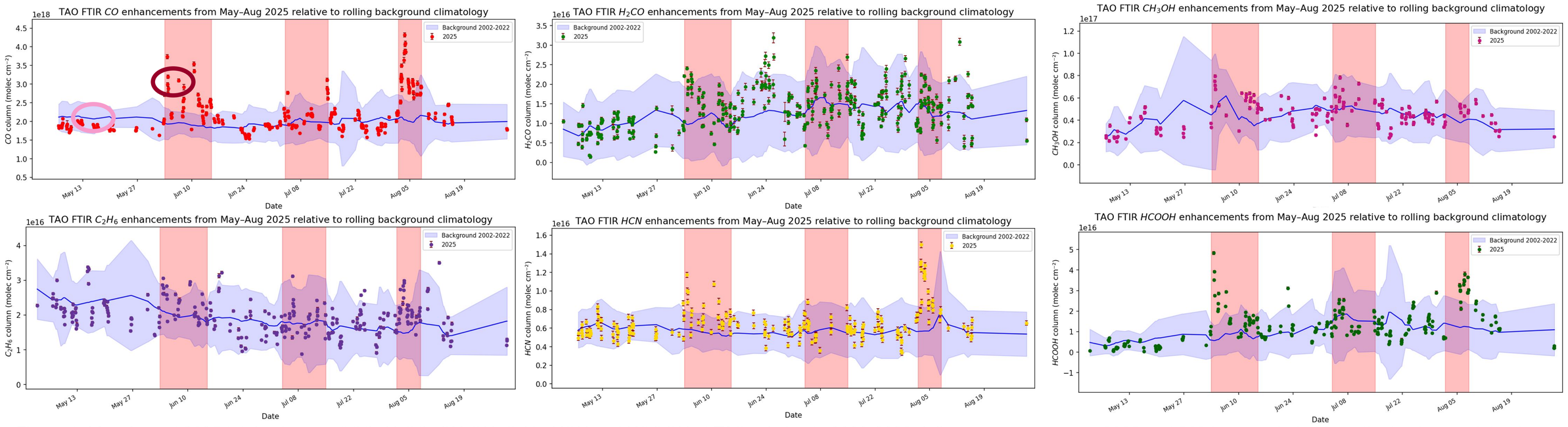

Figure 1: May-August 2025 total columns of CO, H_2CO, CH_3OH, C_2H_6, HCN and HCOOH at TAO relative to 2002-2022 daily summer averages. 2023 and 2024 are excluded from the background due to exceptional wildfire activity in those years [1, 4].

Enhancements of CO, H_2CO, CH_3OH, C_2H_6, HCN and HCOOH were measured by the TAO FTIR, relative to background measurements from previous summers (2002-2022) in summer 2025. Red boxes indicate significant enhancement periods (> background mean + $2\bar{\sigma}$) observed in CO. Figures 1 and 5 show that the lowest air quality day reported, July 13th, has enhancements in CO, H_2CO and CH_3OH.

Figure 2 shows OP-FTIR measurements of near-surface CO during the first enhancement event seen in the TAO FTIR time series. On June 6th, the OP-FTIR CO is enhanced by almost 400 ppb relative to the daily mean 2017-2024 background. The transported smoke plume can be observed in TROPOMI total column CO in Figure 3.

Figure 4: TAO FTIR CO total columns shown by day of calendar year.



Figure 3: TROPOMI CO total columns for two times indicated by circles on Figure 1, showing the extent of the transported smoke plume.

Figure 4 shows that more variability in summer CO is observed in years with a greater number of extreme wildfire events (e.g. 2023, 2025).

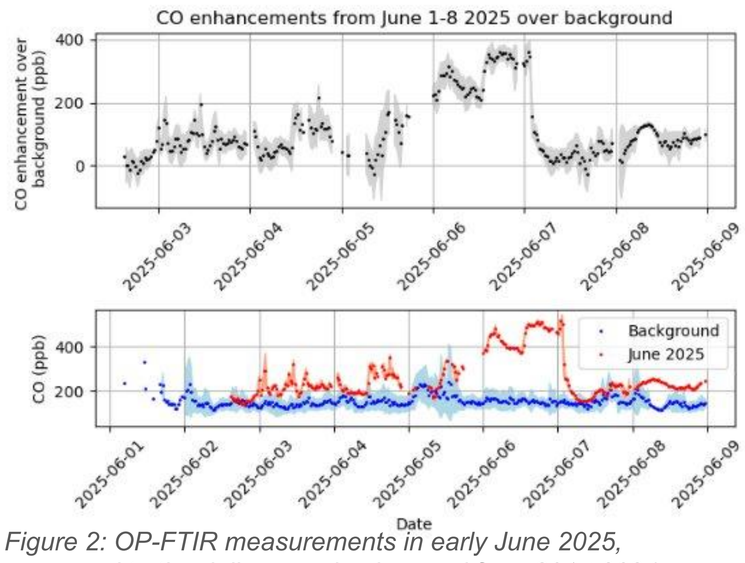

Figure 2: OP-FTIR measurements in early June 2025, compared to the daily mean background from 2017-2024.

Figure 5: Air Quality Index over McLennan Physical Labs, July-August 2025 [from IQAir. World Air Quality Index Rankings, https://www.iqair.com/].

Future Work

The trace gas enhancements observed in Toronto in summer 2025 were due to wildfires in western Canada. The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model will be used to generate back-trajectories to pinpoint plume origins and compared with the locations of active wildfires. Further comparisons to satellite measurements will be used for broader spatial context.

References

[1] C. Tymstra and M. Flannigan. "Canada's landscape fires spreading into uncharted territory". Environmental Research Letters 20.11, 111003 (2025).
[2] D. Griffin et al. "Investigation of CO, C2H6 and aerosols in a boreal fire plume over eastern Canada during BORTAS 2011 using ground- and satellite-based observations and model simulations". Atmospheric Chemistry and Physics 13.20, 10227–10241 (2013).
[3] E. Lutsch et al. "Long-range Transport of NH3, CO, HCN and C2H6 from the 2014 Canadian Wildfires." Geophysical Research Letters 43, 8286–8297 (2016).
[4] V. A. Flood et al. "The impact of the 2023 Canadian forest fires on air quality in southern Ontario". Journal of Geophysical Research: Atmospheres 130.5, e2024JD042254 (2025).

Acknowledgments

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