Unexpected long-range transport of glyoxal and formaldehyde observed from the Copernicus Sentinel-5 Precursor satellite during the 2018 Canadian wildfires (A43J-2964)

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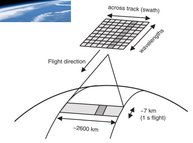
1. Introduction

- Glyoxal (CHO.CHO) and formaldehyde (HCHO) are intermediate products in the oxidation of the majority of volatile organic compounds (VOC). These VOCs are released from biogenic, anthropogenic, and pyrogenic sources.
- CHO.CHO and HCHO tropospheric lifetimes are short during the daytime and at mid-latitudes (few hours), as they are rapidly removed from the atmosphere by their photolysis, oxidation by OH, and uptake on particles/deposition.
- Previous studies demonstrated that CHO.CHO and HCHO can be retrieved from space-borne observations using the DOAS method.
- We present CHO.CHO and HCHO columns retrieved from measurements of the TROPOMI instrument, launched recently on the Sentinel-5 Precursor (S5P) platform in October 2017.
- Strongly elevated amounts of CHO.CHO and HCHO are observed during the fire season in British Columbia, Canada, where a large number of fires occurred in August 2018.
- CHO.CHO and HCHO plumes from individual fire hot-spots are observed in air masses travelling over distances of up to 1500 km, i.e. much longer than expected for the short atmospheric lifetime of CHO.CHO and HCHO.

2. TROPOMI on Sentinel-5 Precursor (S5P)

- The TROPOspheric Monitoring Instrument (TROPOMI) onboard the Copernicus Sentinel-5 Precursor satellite.
- TROPOMI is a nadir-viewing imaging spectrograph with a 2-Dimensional CCD.
- Spectral range from 270 to 500 nm in the UV- VIS, from 675 to 775 nm in the NIR and in a SWIR band from 2305 to 2385 nm.
- Observation of several relevant atmospheric species including CHO.CHO, HCHO, NO_2 and CO.
- Global daily coverage at a spatial resolution of 3.5 km×7 km (7 km×7 km in the SWIR) and equatorial crossing time at 13:30 LT (ascending node).



3. CHO.CHO and HCHO observations

- The retrieval algorithm for CHO.CHO and HCHO uses the Differential Optical Absorption Spectroscopy (DOAS) technique in the UV and VIS spectral ranges.
- A simple profile with a Gaussian distribution having its maximum peak at the altitude of the aerosol layer is used.
- The altitude of the aerosol layer was estimated from profiles retrieved by the CALIPSO and also used in the calculation of the AMFs by the radiative transfer model SCIATRAN.

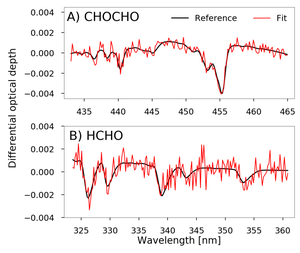


Figure 1. Example fit for CHO.CHO (A) and HCHO (B) from a single measurement of S5P taken on 10 August 2018. The black line depicts the scaled differential cross-section and the red line the fit.

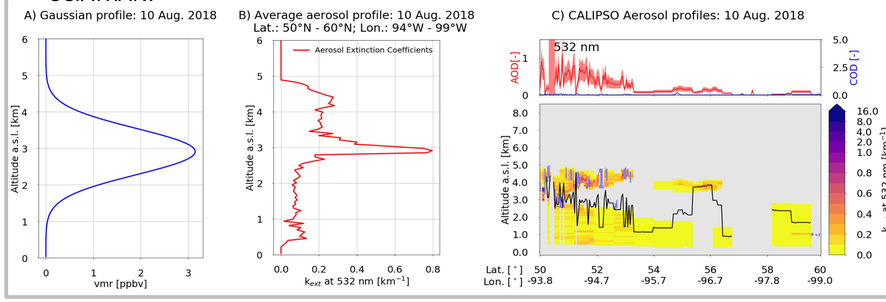


Figure 2. A) CHO.CHO and HCHO profiles assumed in the computation of AMFs. B) CALIPSO average profile of aerosol extinction coefficients (k_{ext}) for all latitudes and longitudes of Figure 2-C, excluding cloudy scenes. C) Top panel: Example of CALIPSO Aerosol profile extinction coefficients retrieved at a wavelength of 532 nm. Aerosol and cloud optical depth are shown as a function of latitude and longitude for every single profile. Bottom panel: Colour-coded k_{ext} for every latitude and longitude in the selected region. Purple spots represent cloudy scenes. The black line depicts the aerosol layer height.

4. Results and discussion

- **CHO.CHO and HCHO** enhancements are not limited to the main fire region but extend over large parts of Canada.

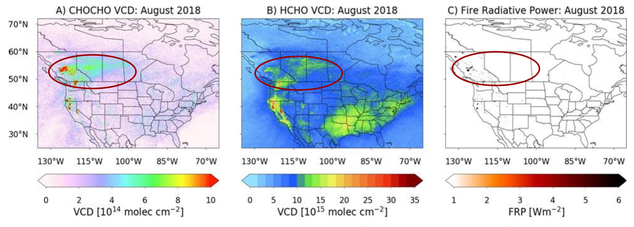


Figure 3. Monthly average of CHO.CHO (A) and HCHO (B) VCDs retrieved from the TROPOMI instrument for August 2018, and over North America. C) shows the integrated FRP from MODIS.

- A passive tracer simulated with FLEXPART spreads over the same area as CHO.CHO and HCHO.
- Plumes cover a distance of about ~1,500 km from the fires.

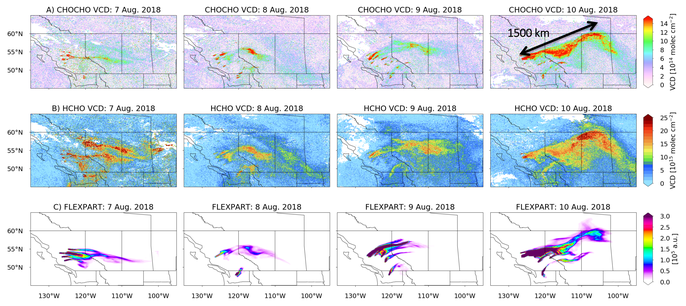


Figure 4. A) and B) Daily CHO.CHO and HCHO VCDs retrieved from S5P measurements for the period 7 to 10 of August 2018. C) Distribution of a tracer with a lifetime of 14.4 hours simulated with FLEXPART.

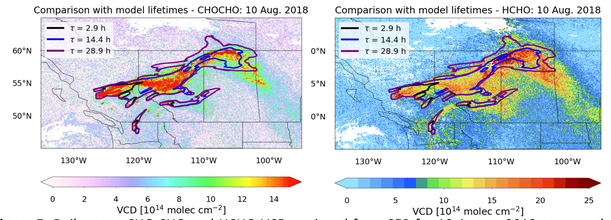


Figure 5. Daily maps CHO.CHO and HCHO VCD retrieved from S5P for 10 August 2018 compared with FLEXPART tracer simulations having three different effective lifetimes (~2.9, 14.4, and 28.9 hours).

- **Potential explanation for enhanced effective lifetimes**
  - **Reason 1:** The lifetimes of CHO.CHO and HCHO could be significantly longer than expected in these biomass burning plumes.
  - **Reason 2:** There could be an efficient recycling process between the gas and aerosol phase, resulting in the observed extended effective lifetimes of CHO.CHO and HCHO.
  - **Reason 3:** The plume could contain glyoxal and formaldehyde precursors which slowly produce additional VOCs along the trajectory, resulting in an apparent increase in lifetimes.

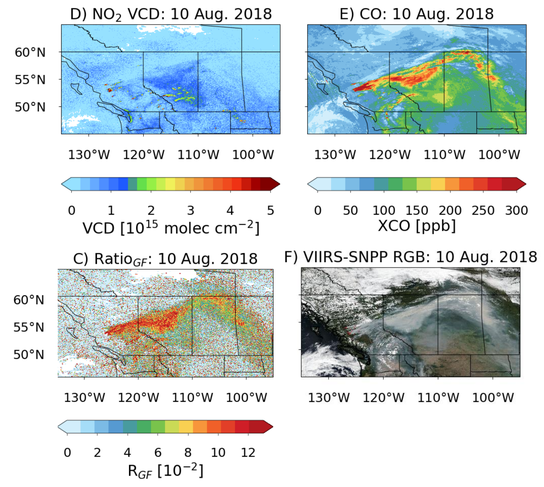


Figure 6. Panels D and E show the NO_2, and CO columns retrieved from S5P measurements for the 10 August 2018. Panel C depicts the calculated ratio of CHO.CHO to HCHO (RGF) for the same day. Panel F shows a true color image of the aerosol distribution from VIIRS for 10 August 2018.

5. Summary and Conclusions

- The retrieval of CHO.CHO and HCHO total column amounts from measurements of the TROPOMI instrument onboard the Sentinel-5P satellite is reported from pyrogenic emissions during the wildfire season in summer 2018 in British Columbia.
- The spatial and temporal pattern of the highest retrieved CHO.CHO and HCHO VCDs are associated with areas having high FRP.
- Extended plumes of elevated CHO.CHO and HCHO amounts are observed on some days downwind of the fires.
- Enhanced CHO.CHO and HCHO columns were found in the S5P data up to 1500 km from their sources.
- An effective tracer lifetime of 28.9 hours needs to be assumed in FLEXPART dispersion simulations to explain these observations.
- The long apparent lifetime of CHO.CHO and HCHO could either be a real increase in atmospheric lifetime due to the specific photochemical conditions in the biomass burning plume or, as we attribute, the presence of longer-lived precursors, which are oxidized to form CHO.CHO and HCHO during transport.

6. Selected references and Acknowledgements

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2. Veefkind, J. P., Aben, I., McMullan, K., Förster, H., de Vries, J., Otter, G., Claas, J., Eskes, H. J., de Haan, J. F., Kleipool, Q., van Weele, M., Hasekamp, O., Hoogeveen, R., Landgraf, J., Snel, R., Tol, P., Ingmann, P., Voors, R., Kruizinga, B., Vink, R., Visser, H., and Levelt, P. F.: TROPOMI on the ESA Sentinel-5 Precursor: A GMES mission for global observations of the atmospheric composition for climate, air quality and ozone layer applications, Remote Sensing of Environment, 2012.

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