The CU airborne SOF instrument: Spectral retrieval and data validation for the 2018 BB-FLUX campaign

University of Colorado Boulder

Christopher F. Lee[1,2], Natalie Kille[2,3], Kyle J. Zarzana[2], Benjamin J. Howard[1,2,4], Teresa Campos[4], Darin W. Toohey[3], Jefferson R. Snider[5], Larry D. Oolman[5], Emily V. Fischer[6], and Rainer Volkamer[1,2,3]

[1]Department of Chemistry, University of Colorado, Boulder, CO; [2]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO; [3]Department of Atmospheric and Oceanic Sciences, University of Colorado, Boulder, CO; [4]National Center for Atmospheric Research, Boulder, CO; [5]University of Wyoming, Laramie, WY; [6]Department of Atmospheric Science, Colorado State University, Fort Collins, CO

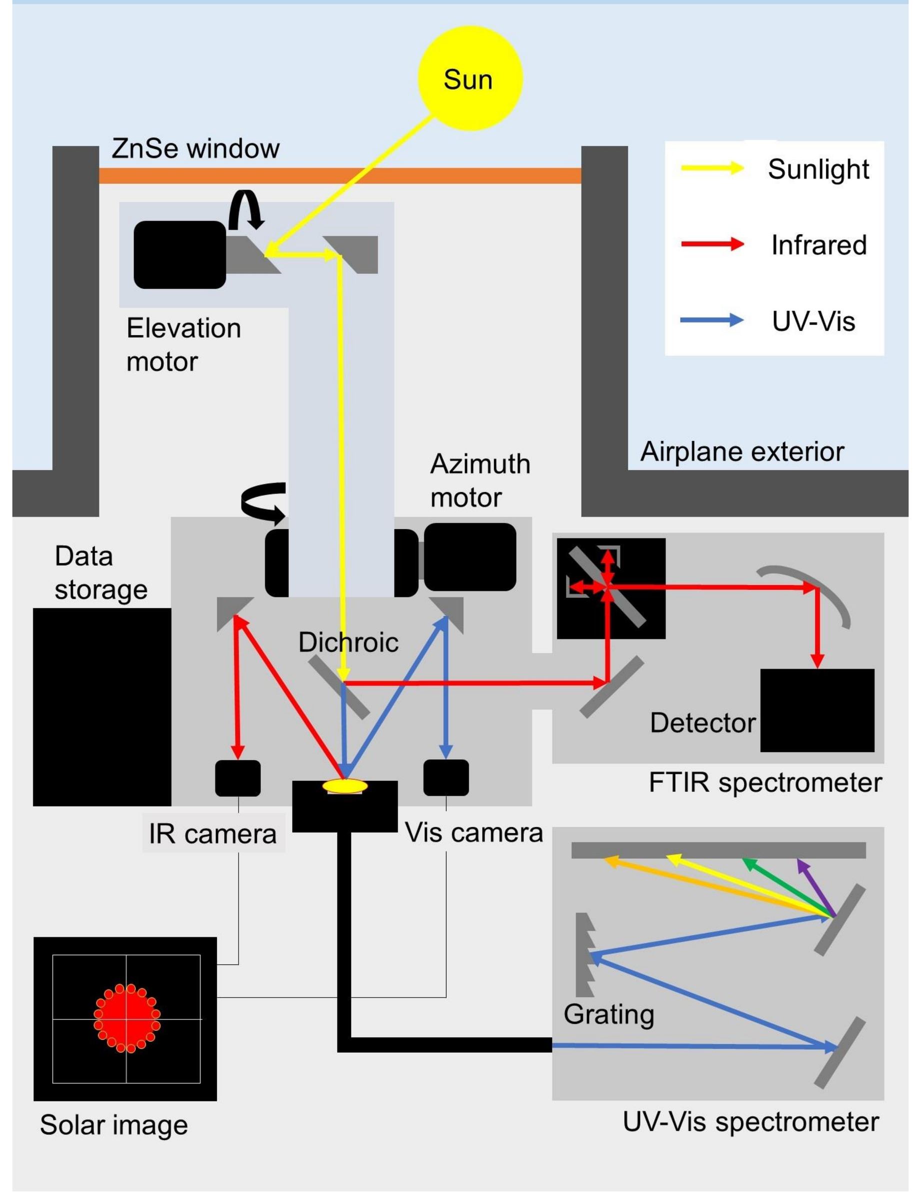
Contact: Christopher.F.Lee@Colorado.edu, Rainer.Volkamer@Colorado.edu

CIRES

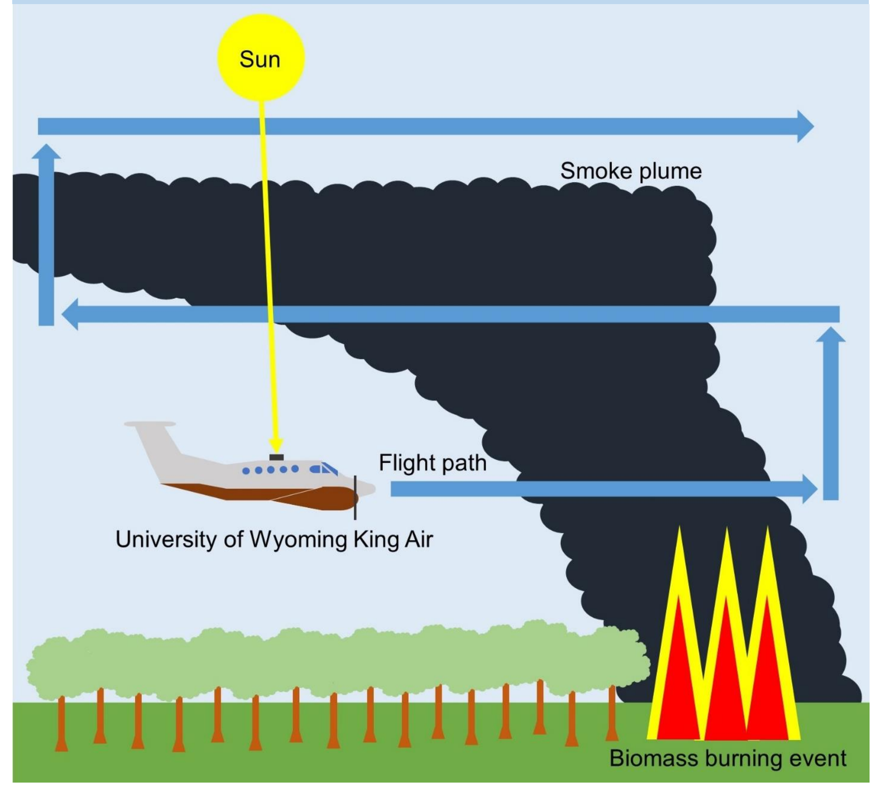
Introduction

Biomass burning emissions are a significant but poorly characterized source of atmospheric trace gases and aerosols. The University of Colorado airborne Solar Occultation Flux instrument (CU SOF), which is capable of directly measuring entire trace gas columns via the direct solar beam, can be used in conjunction with in situ sensors to better characterize biomass burning emissions. To this end, the CU SOF was deployed onboard the University of Wyoming King Air (UWKA) for the duration of the Biomass Burning Fluxes of Trace Gases and Aerosols (BB-FLUX) field campaign. In the course of 37 research flights, BB-FLUX aims were to quantify trace gas and aerosol emission fluxes of wildfire smoke plumes during the 2018 wildfire season in the northwestern United States.

CU SOF concept diagram



2018 BB-FLUX concept diagram



Instrument Overview

The CU airborne SOF instrument consists of a custom-built, motion-stabilized, digital solar tracker coupled to a Fourier Transform Spectrometer (FTS) and three UV-visible grating spectrometers. An early version of the instrument is described here (Kille et al., 2017). The instrument was modified to custom-fit into the aircraft.

The solar tracker uses an internal GPS unit to calculate the solar zenith angle at the current time and position (Baidar et al. 2016). Using an image of the solar disk, custom LabView motion compensation software maintains sun tracking while the airplane is in flight. Two cameras simultaneously record images of the sun. A short-wave infrared and a visible camera simultaneously image the sun, to enable solar tracking through overhead smoke plumes and cirrus cloud cover.

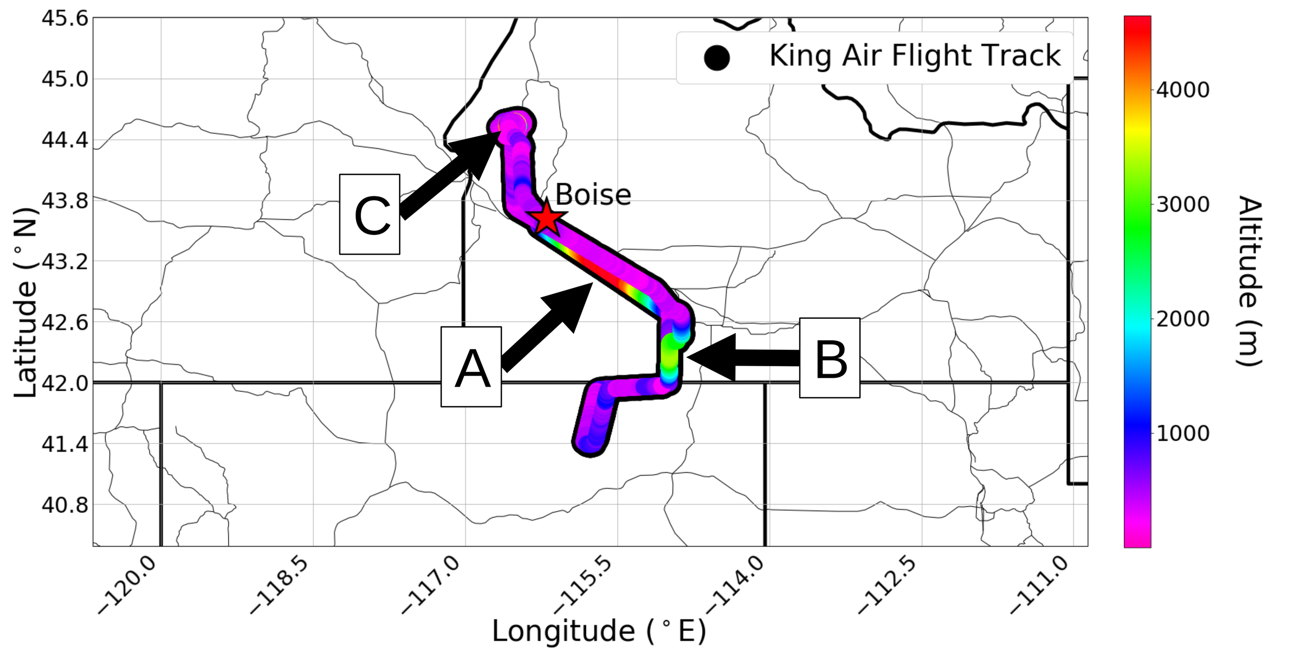
The FTS has spectral resolution of 0.5 cm^{-1}, and two detectors (InSb and MCT) observe the spectral range from 700 – 5000 cm^{-1} (Kille et al. 2017). Four scans are co-added internally, and stored to disk every 2 seconds. Species measured in the infrared include CO, NH_3, C_2H_6, and C_2H_4 using the SFIT4 software package (additional gases in preparation). Post-campaign, collocated measurements were performed alongside a high-resolution FTS at NCAR (not shown).

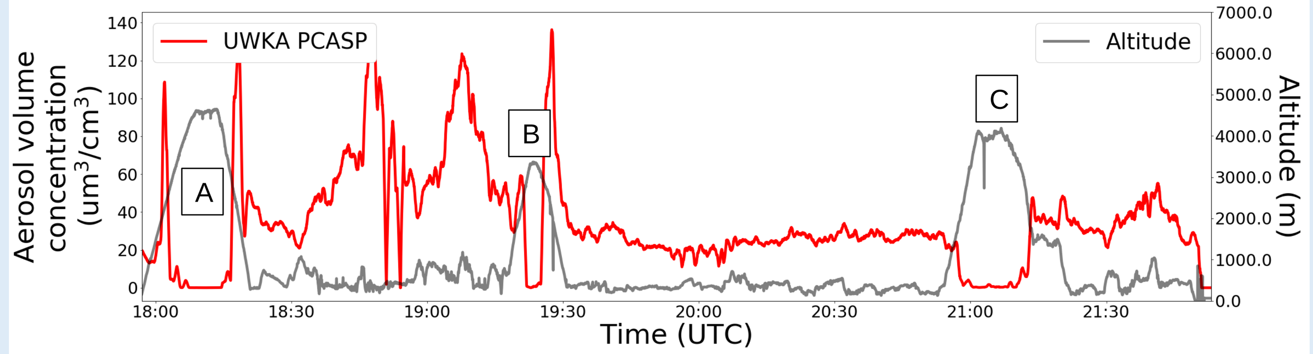
All three UV-visible grating spectrometers have a spectral resolution of ~0.5 nm and spectra are stored to disk every 2 seconds. The green spectrometer (540 – 600 nm) is coupled to the solar tracker, and used to perform Direct-Sun Differential Optical Absorption Spectroscopy (DS-DOAS) measurements of NO_2 and H_2O. The blue (425 – 490 nm) and UV (330 – 375 nm) spectrometers share a common zenith viewport, and are used to perform Zenith-Sky DOAS (ZS-DOAS) measurements of NO_2, HCHO, CHOCHO, HONO, H_2O and O_4. NO_2 is measured by all spectrometers. For a detailed description of the DOAS data see the poster by Zarzana et al. (presented at the AMS 2019 meeting).

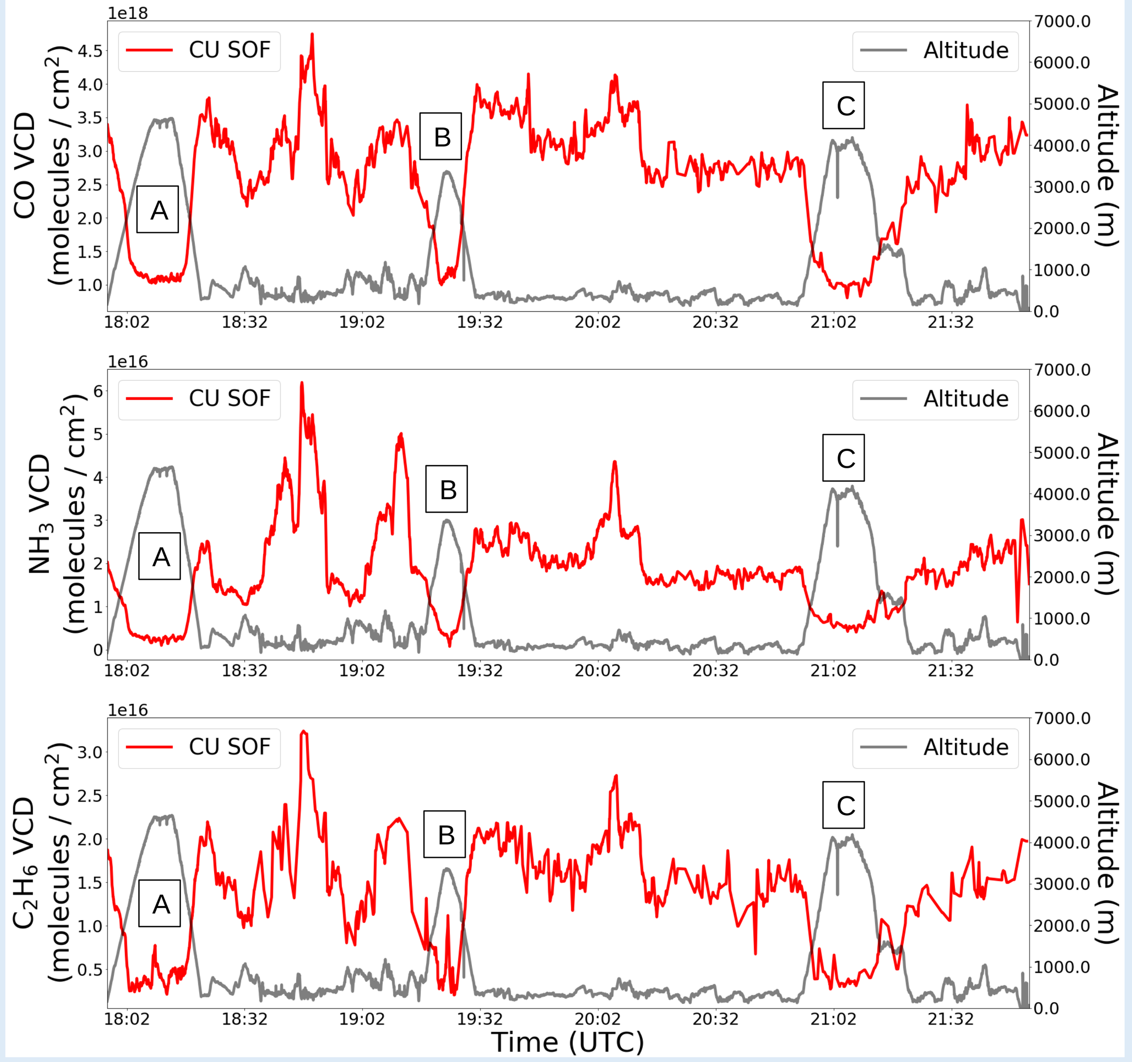
Case Study: South Sugarloaf Fire

A. Flight Overview

The South Sugarloaf Fire was caused by a lightning strike on August 17, 2018, and eventually burned 233,462 acres southwest of Owyhee, Nevada (USDA 2018). Research Flight #18, which studied the smoke plume from the South Sugarloaf Fire, lasted from 17:56 to 21:51 UTC on August 23, 2018. The data shown below is preliminary data from the CU airborne SOF instrument and a University of Wyoming in situ PCASP aerosol instrument (Oolman 2018).



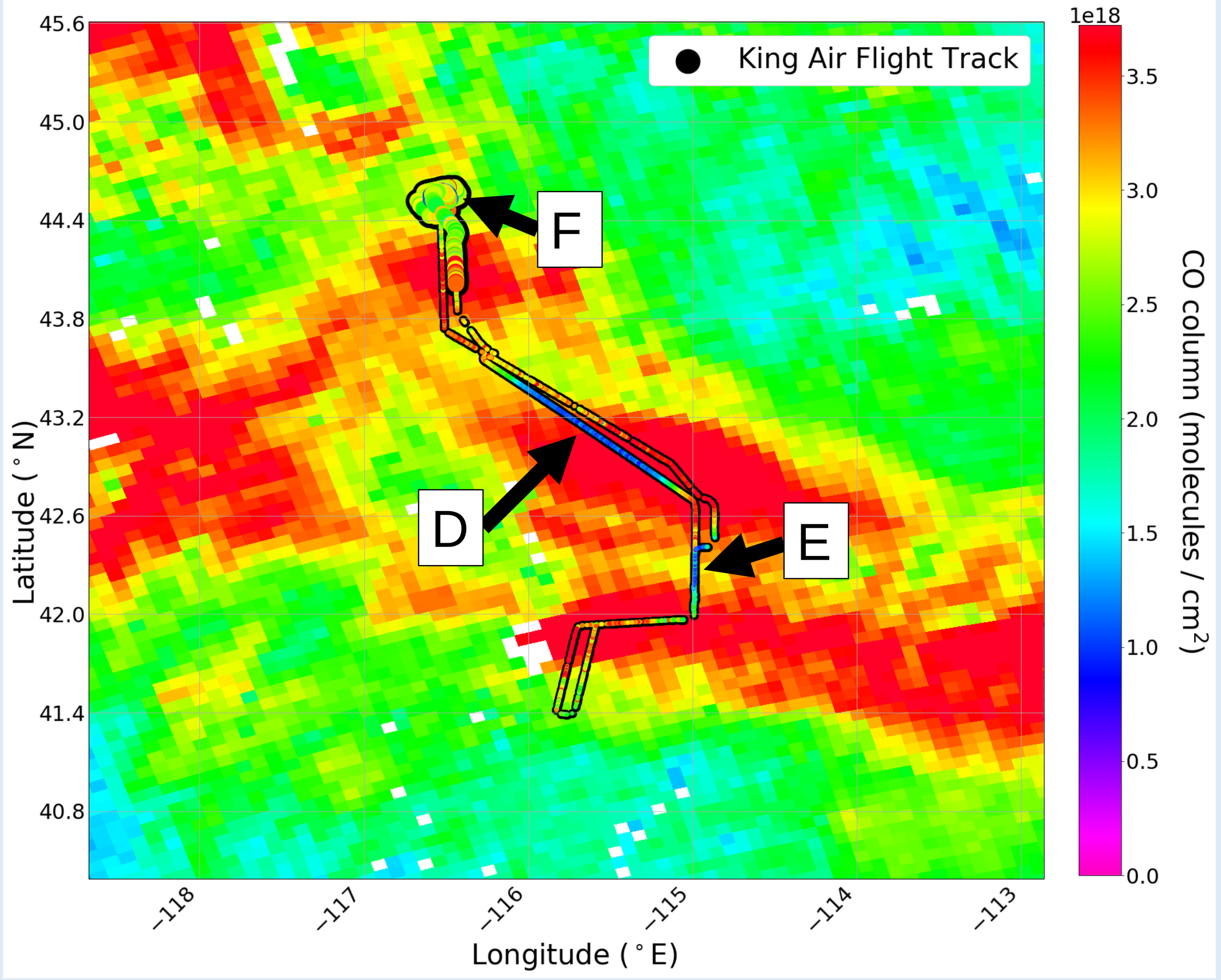


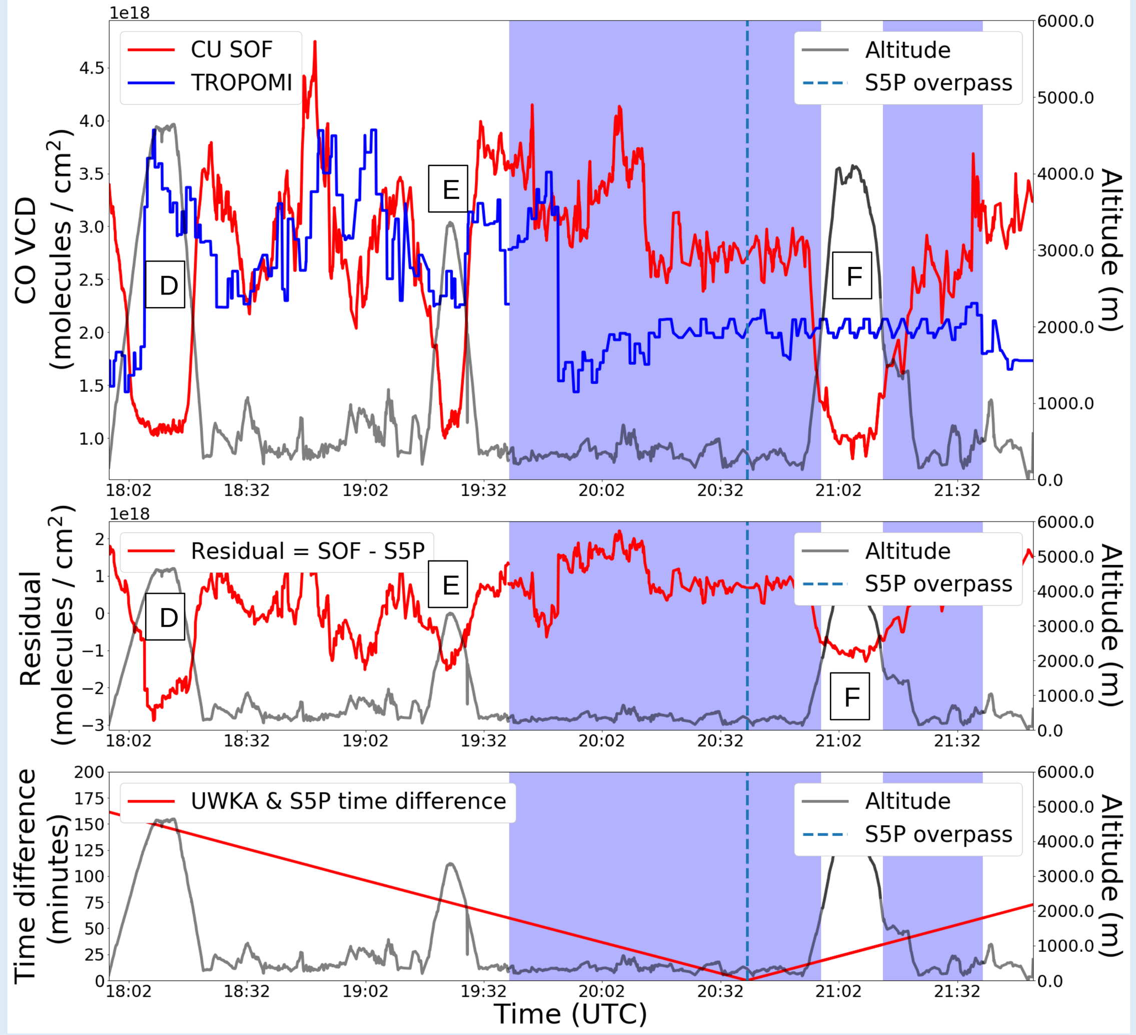


B. Satellite Inter-Comparison

Research Flight #18 was one of several research flights conducted during the BB-FLUX 2018 field campaign which coincided with an overpass (20:38:42 UTC) of the TROPOspheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5 Precursor (S5P) satellite. TROPOMI measures vertical columns of CO, NO_2, HCHO, O_3, CHOCHO, and other trace gases. The coinciding flights afford the first opportunity to compare absorption measurements made top-down by TROPOMI with the geometrically defined bottom-up view by CU airborne SOF, here in the context of optically thick smoke plumes. Aircraft underpasses below the plume capture partial columns above the aircraft.

TROPOMI level 2 CO data were used without further corrections to generate the background color mesh in the map below (European Space Agency 2018). For both the maps and the time series, data collected within one hour of the satellite overpass and below 2000 meters airplane altitude are emphasized. In the time series, the emphasis is denoted by the blue shaded region. In the maps, the emphasis is denoted by a larger marker size.

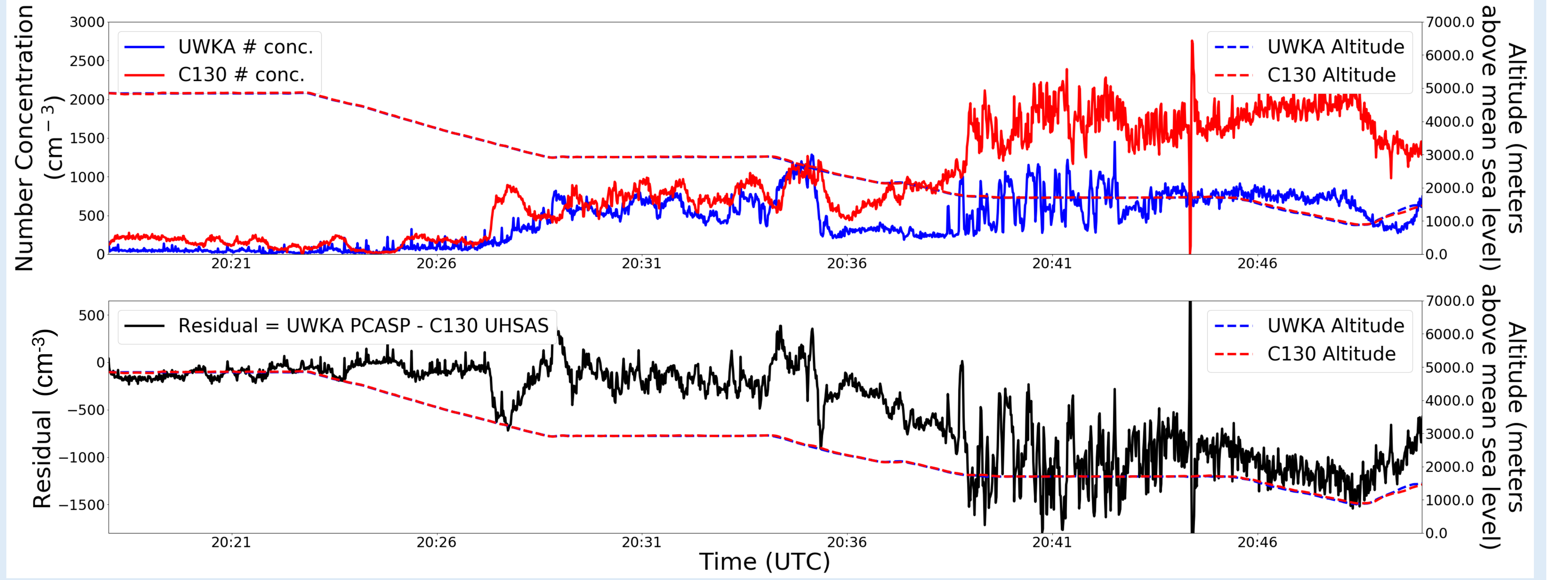


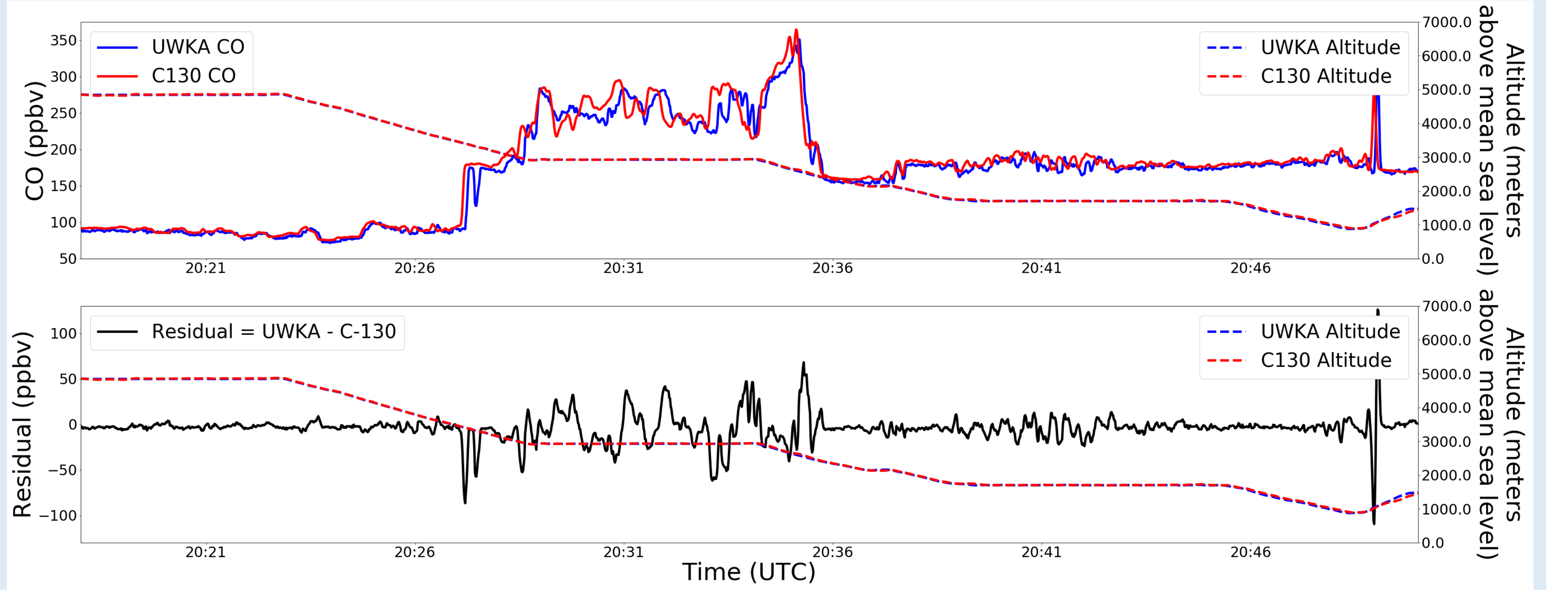


WE-CAN C-130 Inter-Comparison Flights

Two research flights dedicated time to the inter-comparison with the NSF/NCAR C130 aircraft as part of the Western Wildfire Experiment for Cloud Chemistry, Aerosol, Absorption, and Nitrogen (WE-CAN) experiment. A first comparison of in situ CO (UWKA: Aerolaser; C130: Aerodyne TDL) and aerosol number (PCASP; UHSAS) is presented below.

The data shown are from BB-FLUX Research Flight #25, which was conducted on August 28, 2018 alongside WE-CAN Research Flight #16. The BB-FLUX flight lasted from 19:28 to 22:49 UTC, while the WE-CAN flight lasted from 19:41 to 21:48 UTC. All data shown is preliminary data (Campos 2018; Toohey 2018; UCAR/NCAR 2019).





References and Acknowledgements

- Baidar et al. 2016: Development of a digital mobile solar tracker. *Atmospheric Measurement Techniques*, **9**, 963–972, doi:10.5194/amt-9-963-2016.
- Campos, T. 2018: Aerodyne CS-108 miniQCL CO, N_2O and H_2O in situ mixing ratio observations - ICARTT format; Version 1.1. UCAR/NCAR Earth Observing Laboratory. https://data.eol.ucar.edu/dataset/548.016 (Accessed December 10, 2018).
- Campos, T. 2018: 2018 BB-FLUX CO in situ mixing ratio observations; PRELIMINARY. UCAR/NCAR Earth Observing Laboratory. (personal communication).
- European Space Agency, 2018: Level 2 Carbon Monoxide data; Revision 1. European Space Agency. *Sentinel-5P Pre-Operations Data Hub*. https://s5phub.copernicus.eu/ (Accessed December 10, 2018).
- Kille et al. 2017: The CU mobile Solar Occultation Flux instrument: structure functions and emission rates of NH_3, NO_2 and C_2H_6, *Atmospheric Measurement Techniques*, **10**, 373–392, doi:10.5194/amt-10-373-2017.
- Oolman, L., 2018: 2018 BB-FLUX King Air 1 Hz files; PRELIMINARY. University of Wyoming King Air Research. http://flights.uwyo.edu/projects/bbflux18/ (Accessed December 10, 2018).
- Toohey, D. 2018: CVI/UHSAS Data; Version 0.2 [PRELIMINARY]. UCAR/NCAR Earth Observing Laboratory. https://data.eol.ucar.edu/dataset/548.026 (Accessed December 10, 2018).
- UCAR/NCAR Earth Observing Laboratory, 2019: PRELIMINARY Low Rate (LRT - 1 sps) Navigation, State Parameter, and Microphysics Flight-Level Data; Version 0.3 [PRELIMINARY]. UCAR/NCAR Earth Observing Laboratory. https://data.eol.ucar.edu/dataset/548.002. (Accessed December 10, 2018).
- USDA Forest Service, Fire and Aviation Management. *InciWeb the Incident Information System*. http://inciweb.nwcg.gov/ (Accessed December 10, 2018).

The BB-FLUX project is funded by the U.S. National Science Foundation (NSF) award AGS-1754019 (PI: R. Volkamer). Christopher F. Lee acknowledges support for undergraduate summer research from the University of Colorado, Boulder. We thank the pilots and the crew at University of Wyoming for supporting the UWKA deployment.