GSFC TOLNet Lidar

Tropospheric ozone profiles are retrieved from the ground-based NASA GSFC TROPospheric OZone DIfferential Absorption Lidar (GSFC TROPOZ DIAL) in Greenbelt, MD (38.99 N, 76.84W, 57m a.s.l.), from 200m to 12 km. This lidar has been used to examine scientific topics such as boundary layer dynamics, diurnal O_3 enhancements, frontal-range air recirculation and land-sea breeze impact on O_3, air pollution transport, and stratosphere-troposphere exchange (STE). Furthermore, the GSFC TROPOZ system is transportable and has been relocated to support multiple field campaigns such as DISCOVER-AQ Colorado (http://discover-aq.larc.nasa.gov/), FRAPPÉ (https://www.eol.ucar.edu/field_projects/frappe), and KORUS-AQ (https://espo.nasa.gov/home/korus-aq/content/KORUS-AQ).

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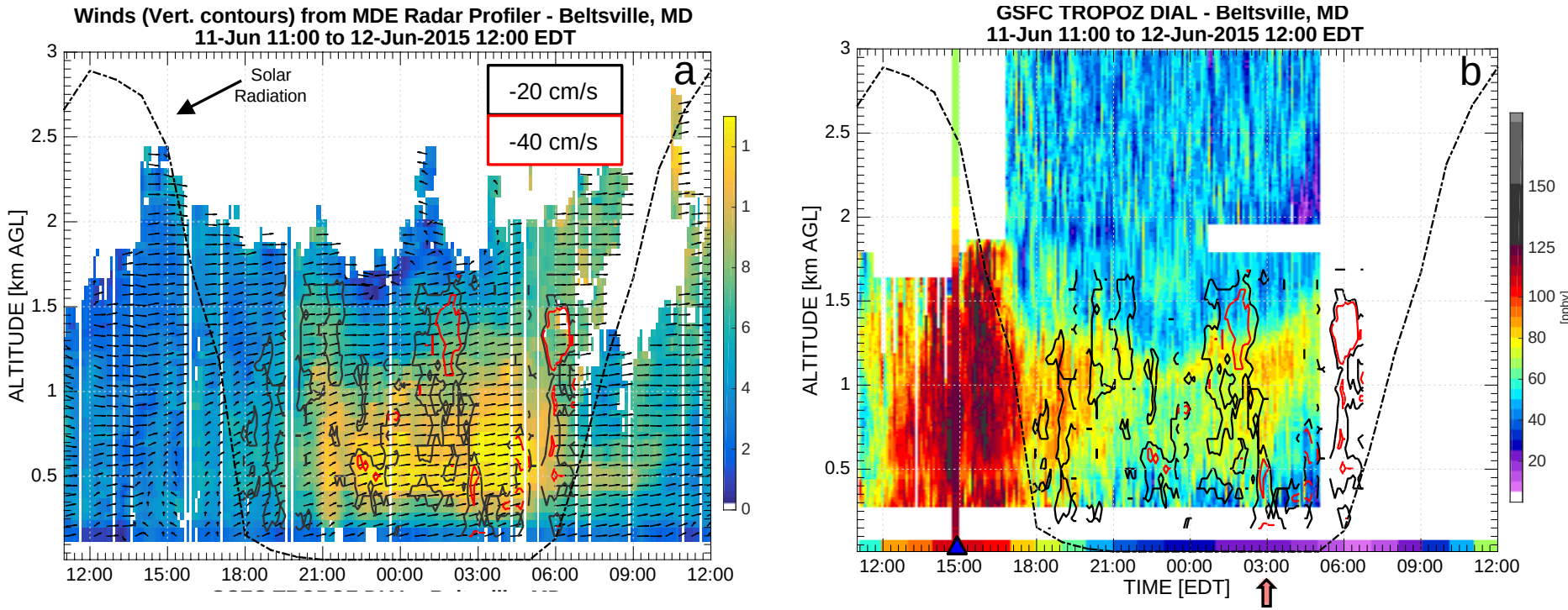
1. Impacts of Biomass Burning on Ozone Enhancement Within an Urban Region

Canadian wildfire smoke impacted air quality across the northern Mid-Atlantic (MA) of the United States (US) from 9-12 June, 2015. An exceedance of the 2008 75 ppb National Ambient Air Quality Standard (NAAQS) for ozone (O_3) resulted, which caused the Baltimore, Maryland area to be incompliant of EPA's new 2015 70 ppb O_3 standard. High resolution in situ and remotely sensed observations were available as the smoke plume moved through the monitoring network of the Maryland Department of the Environment (MDE) and partnering organizations. Results show smoke tracers at the surface were spatially correlated with maximum 8-hour O_3 concentrations in the MA, suggesting smoke played a role increasing O_3 by 20-30 ppb on 11 June compared to 10 June. TROPOZ ozone lidar observations during the event have been critical in understanding the O_3 analyses during the event. Furthermore, coincident measurements between the O_3 lidar and wind profiler indicate a nocturnal low level jet (NLLJ) was observed in the evening hours after the high O_3 event and eventually impacted the surface.

Important figures from this work are in the following slide and the full study is currently in preparation for publication.

1. Impacts of Biomass Burning on Ozone Enhancement Within an Urban Region



Wind profile (left) and TROPOZ O_3 observations (right) on 11-12 June 2014 at Beltsville, MD.

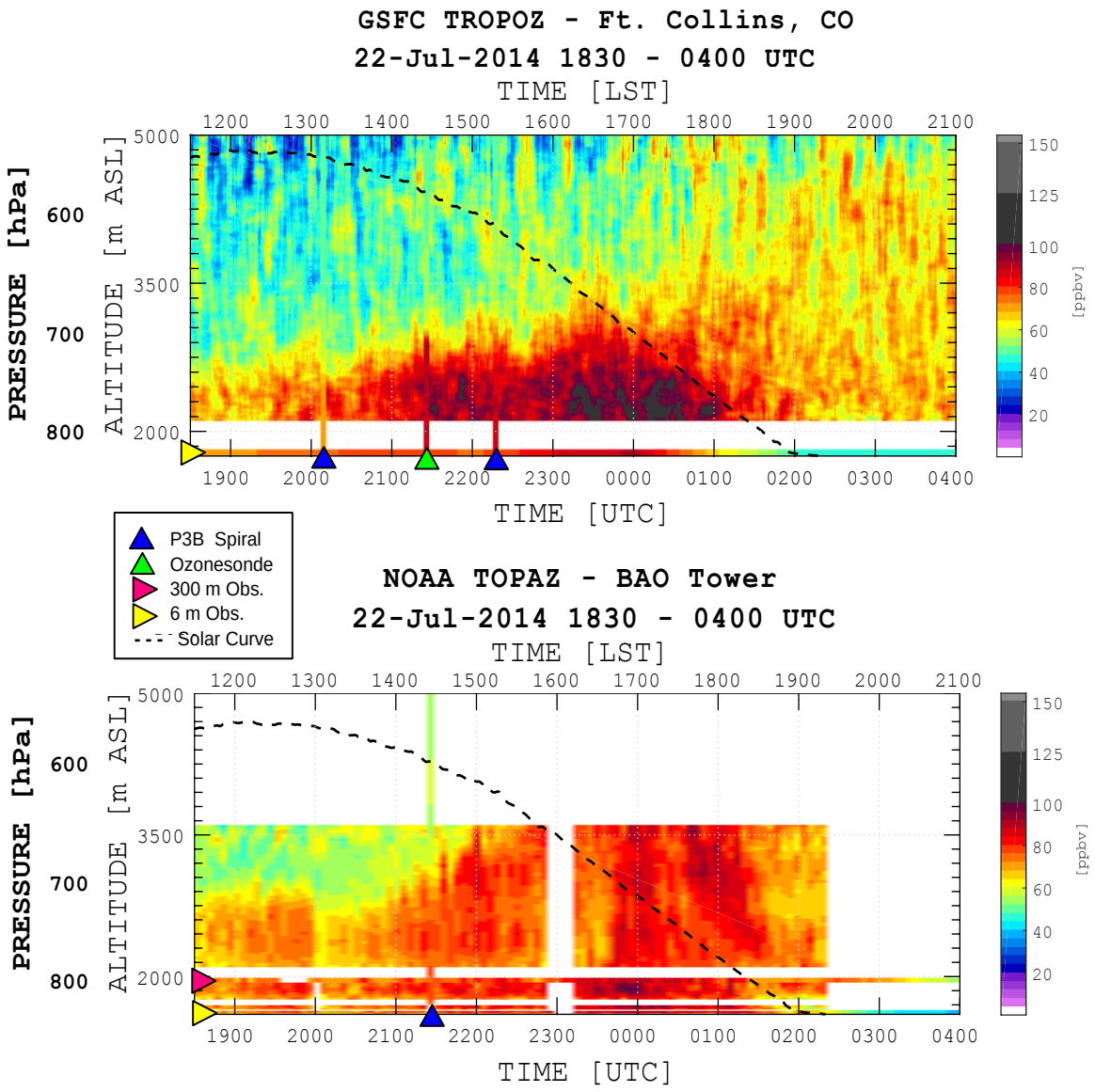
- **GSFC TROPOZ lidar observed large O_3 enhancement in Beltsville, MD on June 11-12, 2015 possibly associated with biomass burning.**
- **Peak O_3 concentrations aloft occur after solar radiation maximum.**
- **Residual Layer aloft in context of nocturnal low-level jet.**

2. Evaluation of Frontal-range Air Recirculation

A high-ozone O_3 pollution episode was observed on 22 July 2014 during the concurrent "Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality" (DISCOVER-AQ) and "Front Range Air Pollution and Photochemistry Experiment" (FRAPPE) campaigns. Surface O_3 monitors at three regulatory sites exceeded the EPA 2008 NAAQS daily maximum 8-hr average (MDA8) of 75 ppbv. To further characterize the polluted air mass and assess transport throughout the event, measurements are presented from TROPOZ O_3 and wind profilers, ozonesondes, aircraft, and surface monitoring sites. Observations indicate thermally-driven upslope (easterly) flow was established throughout the Colorado Front Range during the pollution episode. As the thermally-driven flow persisted throughout the day, O_3 concentrations increased and affected high-elevation Rocky Mountain sites. These observations, coupled with modeling analyses, demonstrate an easterly return flow of polluted air aloft, indicating the mountain-plains solenoid circulation was established and impacted surface conditions within the Front Range.

Important figures from this work are in the following slide and the full study is currently in preparation for publication.

2. Evaluation of Frontal-range Air Recirculation



- **GSFC TROPOZ deployed in the DISCOVER AQ Campaign in July-August 2014.**
- **Observations during this time period indicate that:**

  1) Frontal upslope flow transported locally produced O_3 to high mountain elevation sites

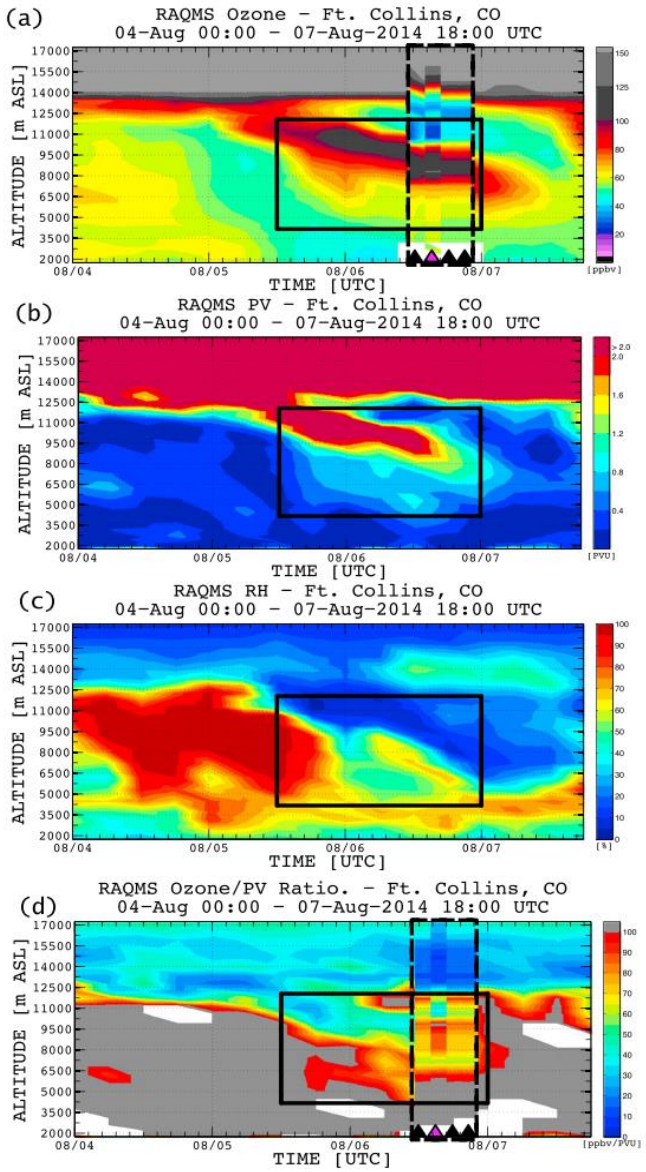
  2) Upslope to downslope reversal elevated O_3 by 10-30 ppbv impacting sites near the eastern ridge of the Rocky Mountains.

3. Characterizing the Impact of STE Events

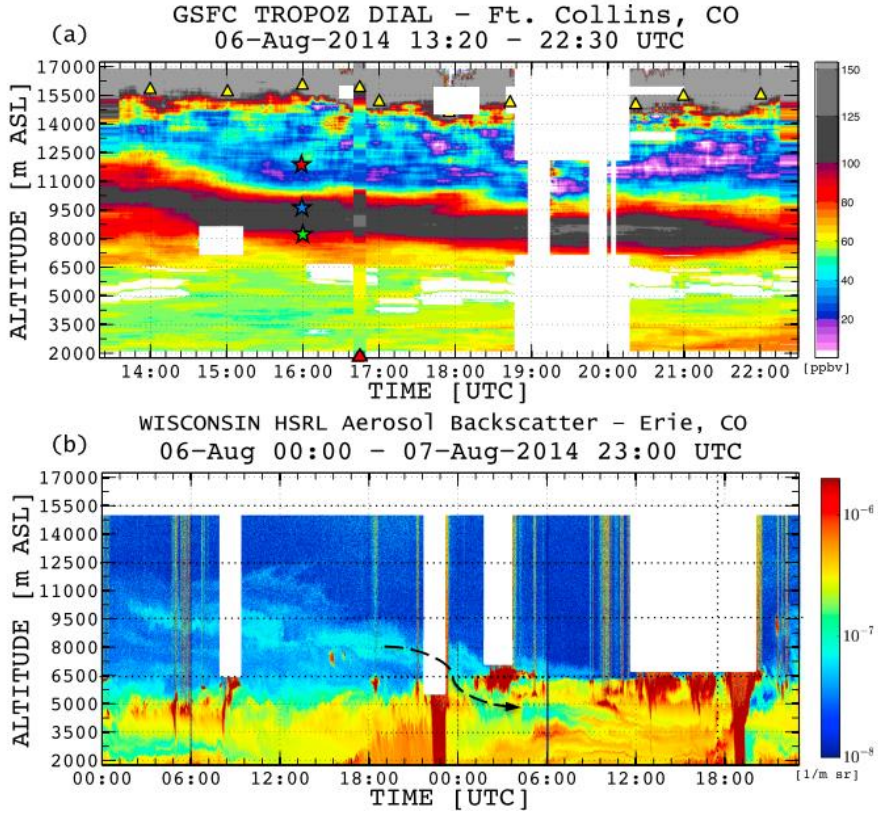
This study examined the evolution of a Stratospheric to Tropospheric Exchange (STE) event from 4 to 8 August 2014 at Fort Collins, CO. The event was measured by the GSFC TROPOZ lidar, the University of Wisconsin High Spectral Resolution Lidar, and multiple ozonesondes. Based on the TROPOZ observations during this time, it was found that STE events have largely contributed to an additional 10–30 ppbv of O_3 at Fort Collins. The RAQMS model simulated O_3 agrees well with the TROPOZ O_3 concentrations during the STE event. To extend the analysis to other times, the modeled O_3 to potential vorticity (PV) ratio is used as a tracer for stratospheric air residing below the tropopause. It is found that at Fort Collins, CO, depending on season from 2012 to 2014, between 18 and 31% of tropospheric O_3 corresponds to stratospheric air. A relationship to determine the lifetime of stratospheric air below the tropopause is derived using the simulated ratio tracer. Results indicate that throughout summer 2014, 43% of stratospheric air resided below the tropopause for less than 12 hours. However, nearly 39% persisted below the tropopause for 12–48 hours and penetrated deeper in the troposphere.

Important figures from this work are in the following slide and the full study can be found at: Sullivan, J. T., T. J. McGee, A. M. Thompson, R. B. Pierce, G. K. Sumnicht, L. W. Twigg, E. Eloranta, and R. M. Hoff (2015), Characterizing the lifetime and occurrence of stratospheric-tropospheric exchange events in the rocky mountain region using high-resolution ozone measurements, J. Geophys. Res. Atmos., 120, 12,410–12,424, doi:10.1002/2015JD023877.

3. Characterizing the Impact of STE Events



RAQMS simulated a) O_3, b) PV, c) RH, and d) O_3/PV Ratio.



a) TROPOZ O_3 and b) HSRL measured aerosol backscatter.

- TROPOZ lidar observations show a STE event occurring on 6 August 2014 with highly elevated O_3 mixing ratios (> 100 ppb).
- RAQMS simulated O_3/PV ratios were used to determine STE lifetimes and show that around 33% of STE last >12 hours near Fort Collins, CO.

4. Lidar Observations in Support of Discover-AQ Colorado

The GSFC TROPOZ DIAL was deployed to Ft. Collins, CO during the 2014 DISCOVER AQ campaign. The NASA P3B and ozonesondes are shown over the site while the TROPOZ is taking measurements.

In support of the DISCOVER AQ field campaign the GSFC TROPOZ lidar took nearly continuous O_3 observations during the summer of 2014. During this time, the system observed numerous processes controlling O_3 spatio-temporal variability with enhancements associated with stratospheric transport, frontal-range air circulation, and anthropogenic emissions. The GSFC TROPOZ lidar provided critical observations of O_3 vertical profiles which were inter-compared with numerous measurement platforms and chemical transport models and have assisted in studies of varying processing impacting tropospheric O_3.

Supporting Information and Publications

Instrument Description

Sullivan, J. T., T. J. McGee, G. K. Sumnicht, L. W. Twigg, and R. M. Hoff. "A mobile differential absorption lidar to measure sub-hourly fluctuation of tropospheric ozone profiles in the Baltimore–Washington, DC region." *Atmospheric Measurement Techniques* 7, no. 10 (2014): 3529-3548. (http://www.atmos-meastech.net/7/3529/2014/).

Intercomparion Results Between TROPOZ and Other TOLNet Lidars

Sullivan, John T., Thomas J. McGee, Russell DeYoung, Laurence W. Twigg, Grant K. Sumnicht, Denis Pliutau, Travis Knepp, and William Carrion. "Results from the NASA GSFC and LaRC ozone lidar intercomparison: New mobile tools for atmospheric research." *Journal of Atmospheric and Oceanic Technology* 32, no. 10 (2015): 1779-1795. (http://journals.ametsoc.org/doi/abs/10.1175/JTECH-D-14-00193.1).

Retrieval Optimization

Sullivan, J. T., T. J. McGee, T. Leblanc, G. K. Sumnicht, and L. W. Twigg. "Optimization of the GSFC TROPOZ DIAL retrieval using synthetic lidar returns and ozonesondes–Part 1: Algorithm validation." *Atmospheric Measurement Techniques* 8, no. 10 (2015): 4133-4143. (http://www.atmos-meas-tech.net/8/4133/2015/amt-8-4133-2015.html).