UAH TOLNet Lidar

The Rocket-city O_3 Quality Evaluation in the Troposphere (RO_3QET) lidar is a Differential Absorption Lidar (DIAL) and is located on the campus of University of Alabama in Huntsville (UAH) at 34.72N and 86.65W at ~206-m ASL. This lidar has been used to examine scientific topics such as air pollution transport, stratosphere-troposphere exchange (STE), boundary layer entrainment, impact of wildfires on ozone (O_3), and lightning-generated O_3. Examples of interesting results from these studies are presented on the following slides. The UAH TOLNet lidar has also supported multiple field campaigns focusing on air quality in the southeast United States such as SENEX (http://www.esrl.noaa.gov/csd/projects/senex/) and $SEAC^4RS$ (http://www-air.larc.nasa.gov/missions/seac4rs/).

Please contact Mike Newchurch (mike@nsstc.uah.edu) or Shi Kuang (kuang@nsstc.uah.edu) for further information regarding these research topics. For more information about the Atmospheric Chemistry Department at UAH please visit: http://nsstc.uah.edu/atmchem/

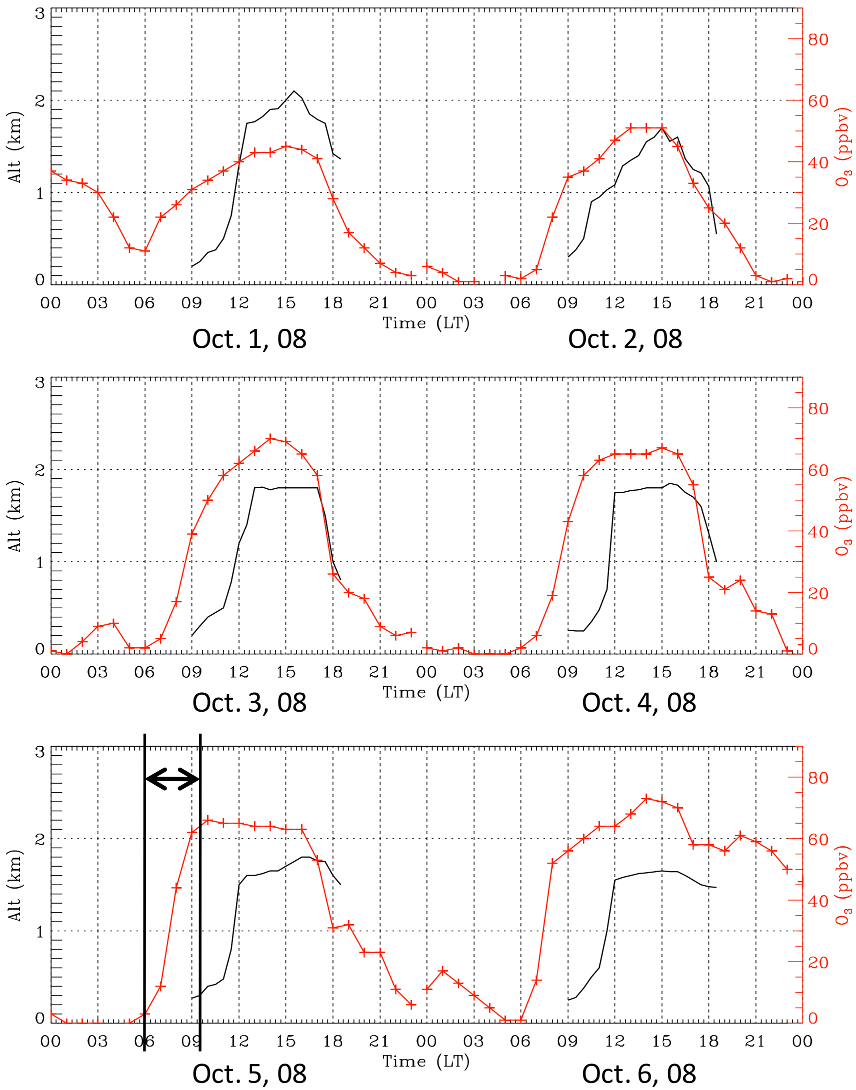
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

1. Boundary-layer Ozone Enhancement Due to Low-level Transport

A previous study was conducted focusing on an enhancement in the nocturnal residual layer which was observed by the UAH TOLNet O_3 lidar from the late evening to midnight on 4 October 2008. The well-correlated O_3, aerosol, water vapor, and wind structures suggested a low-level jet was responsible for this O_3 enhancement. HYSPLIT backward trajectories supported this conclusion with southerly transport suggesting Birmingham, AL as the source. Correspondingly, the higher increasing rate of surface O_3 observed on the morning of 5 October can be explained by the entrainment into the mixed layer of higher O_3 aloft on this day as compared with 4 October. This case study demonstrated the importance of continuous high-resolution lidar profiling for capturing short-duration O_3 variations in the lower troposphere.

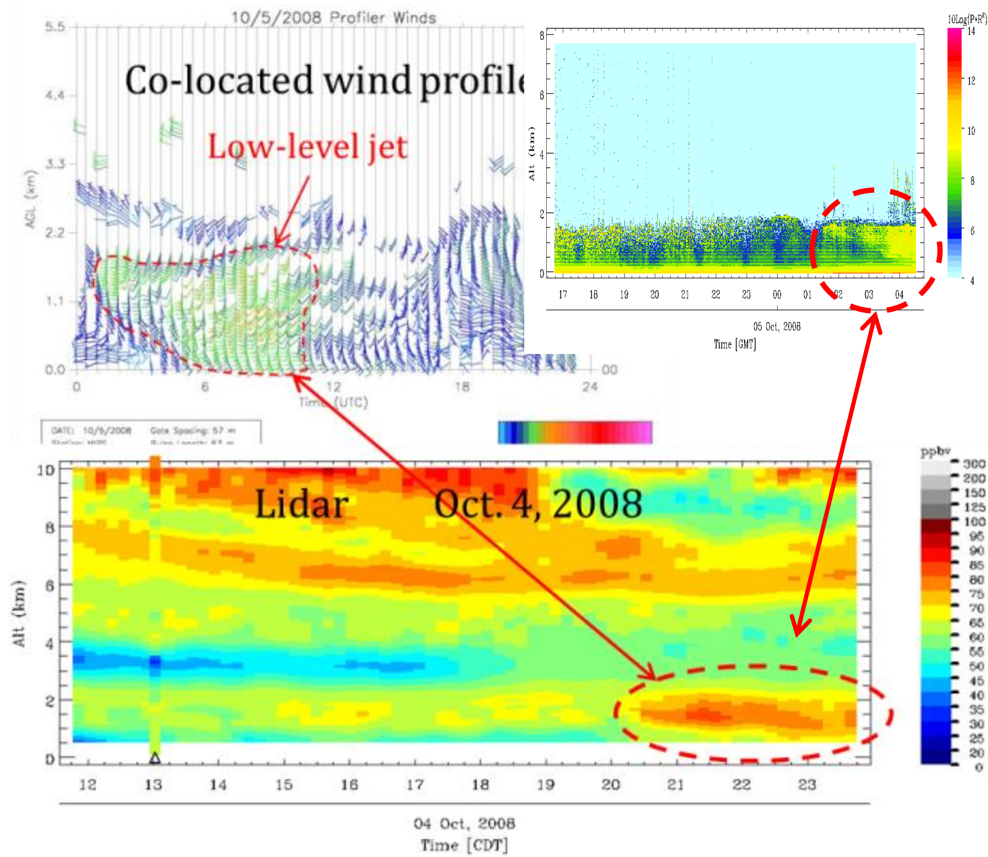
Important figures from this work are in the following slide and the full study can be found at: Kuang, S., M. J. Newchurch, J. Burris, L. Wang, P. Buckley, S. Johnson, K. Knupp, G. Huang, and D. Phillips (2011), Nocturnal ozone enhancement in the lower troposphere observed by lidar, Atmos. Environ., 45, 6078-6084, doi:10.1016/j.atmosenv.2011.07.038.

1. Boundary-layer Ozone Enhancement Due to Low-level Transport



Surface O_3 and convective boundary layer height

A collocated Mobile Integrated Profiling System (MIPS) provides aerosol backscatter, wind/RH/T profiles, and other surface data.



Surface O_3 enhancement before 10AM on Oct. 5 due to the low-level transport on the previous day

[*Kuang et al.,* 2011]

2. Quantify the Impact of STE on Tropospheric Ozone

This study examined O_3 structures measured by the UAH TOLNet lidar on 27–29 April 2010 originating from a stratosphere-to-troposphere transport event associated with a cutoff cyclone and tropopause fold. During this time, the tropopause reached as low as 6 km and the stratospheric intrusion resulted in a 2-km thick elevated O_3 layer with values between 70 and 85 ppbv. The STE event was evaluated using meteorological fields and potential vorticity (PV) structures derived from the North American Mesoscale model. The 2-PVU (PV unit) surface, defined as the dynamic tropopause, was able to capture the variations of the O_3 tropopause estimated from the ozonesonde and lidar measurements. Overall, tropospheric O_3 exhibited large variability due to the complicated mixing processes associated with the STE. Low O_3 and large variability were observed in the mid-troposphere after the stratospheric intrusion due to the westerly advection including the transition from a cyclonic system to an anticyclonic system.

Important figures from this work are in the following slide and the full study can be found at: Kuang, S., M. J. Newchurch, J. Burris, L. Wang, K. Knupp, and G. Huang (2012), Stratosphere-to-troposphere transport revealed by ground-based lidar and ozonesonde at a midlatitude site, J. Geophys. Res., 117, D18305, doi:10.1029/2012JD017695.

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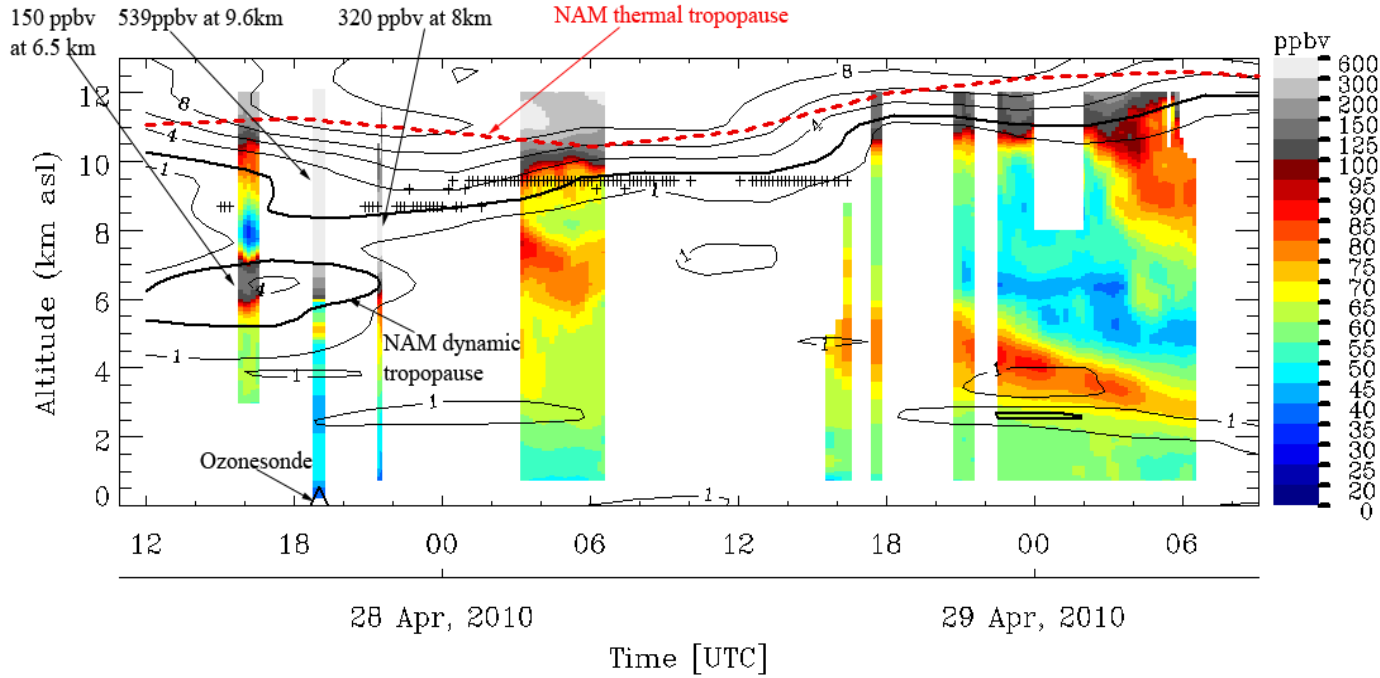
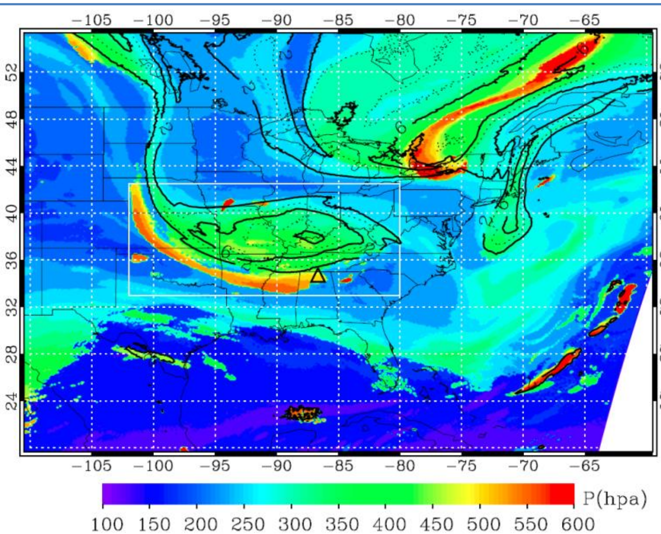
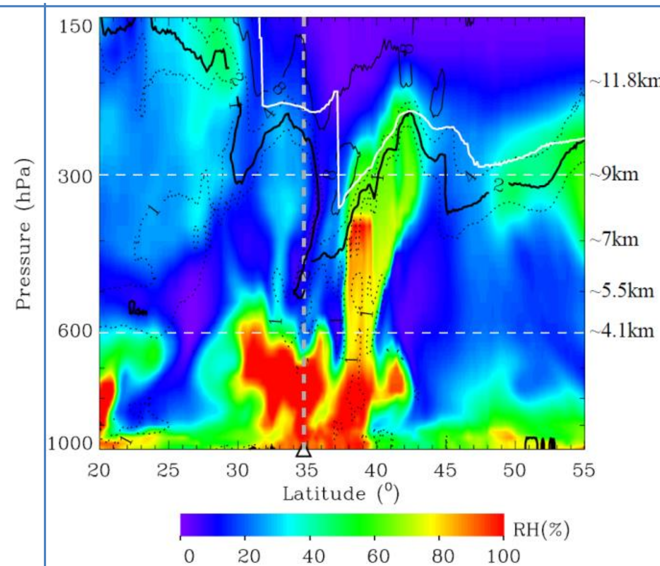
[*Kuang et al.* 2012]

Ozone lidar and ozonesonde measurements, as well as the MPR-observed and model-derived tropopause.





IPV at 320-K isentropic surface



Pressure-altitude cross-section of PV (black lines), RH (color contours), and tropopause pressure, at 86.65°W longitude at 1200 UTC 27 April 2010 derived from the NAM model.

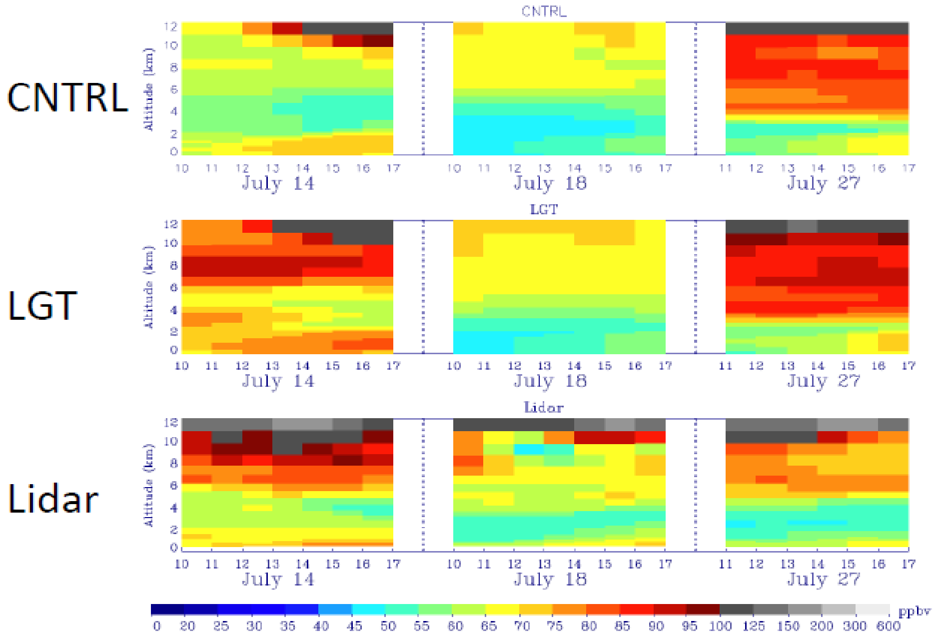
3. Ozone Enhancement from Lightning produced NO_x

This study evaluated hourly variations of tropospheric-ozone profiles measured by the UAH TOLNet lidar on July 14, 18, and 27, 2011. These O_3 lidar data were compared with two WRF-Chem simulations, one with lightning NO (LNO) emissions (LGT) and the other without (CNTRL). On July 14, 2011, the O_3 lidar observed an O_3 laminar structure with elevated O_3 concentrations of 65-80 ppbv below 2 km, low O_3 (50-65 ppbv) between 2 and 5 km, and high O_3 up to 165 ppbv between 5 and 12 km AGL. WRF-Chem simulations, in conjunction with backward trajectory analysis, suggest that lightning events occurring within upwind regions resulted in an O_3 enhancement of 28 ppbv at 7.5 km AGL over Huntsville. On July 27, LNO emissions were transported to Huntsville from upwind and accounted for 75% of NO_x and an 8.3 ppbv of O_3 enhancement at ~10 km.

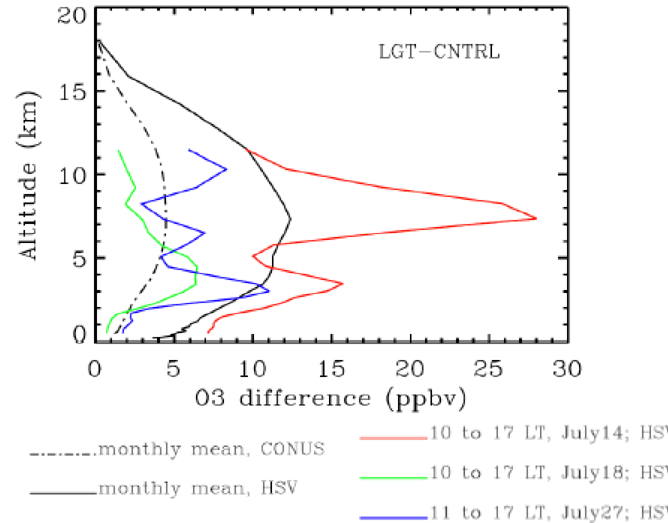
Important figures from this work are in the following slide and the full study can be found at: Wang, L., M. Cook, M. J. Newchurch, K. Pickering, A. Pour-Biazar, S. Kuang, W. Koshak, and H. Peterson (2015), Tropospheric ozone lidar data evaluation of the lightning-induced ozone enhancement simulated by the WRF/Chem model, Atmos. Environ., 115, 185-191.

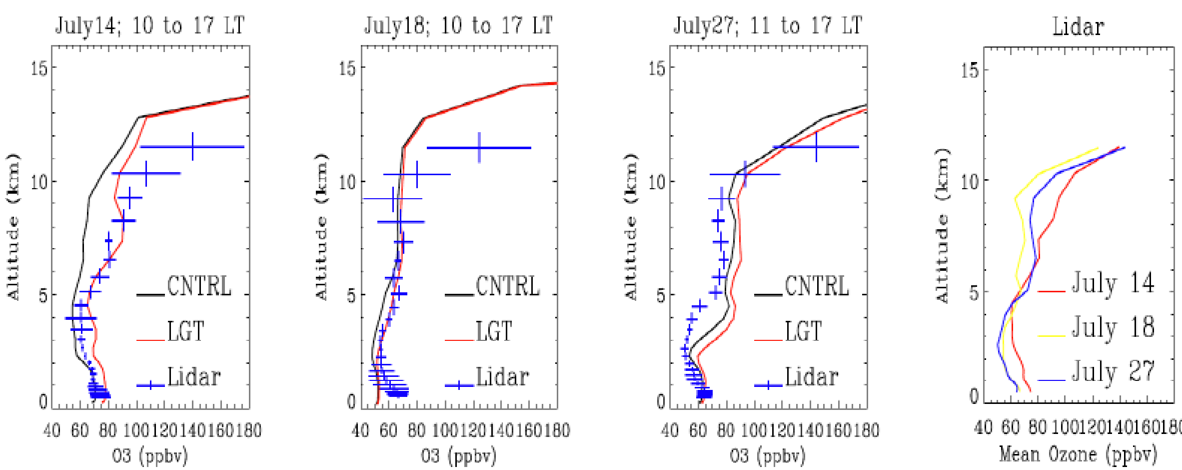
3. Ozone Enhancement from Lightning produced NO_x

Modeled and lidar-measured O3



Model-simulated O3 enhancement due to lightning

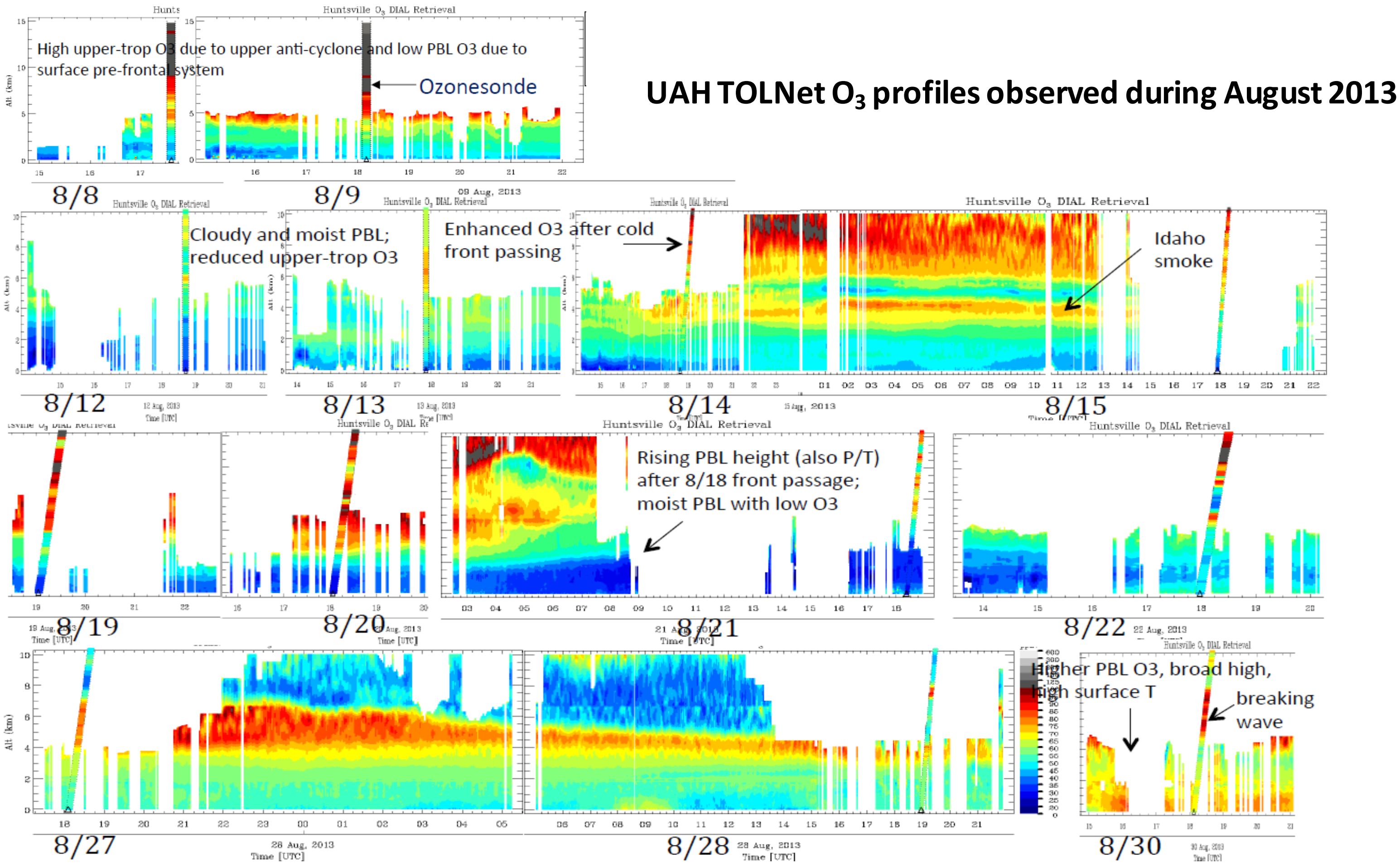




Daily lidar-model comparisons

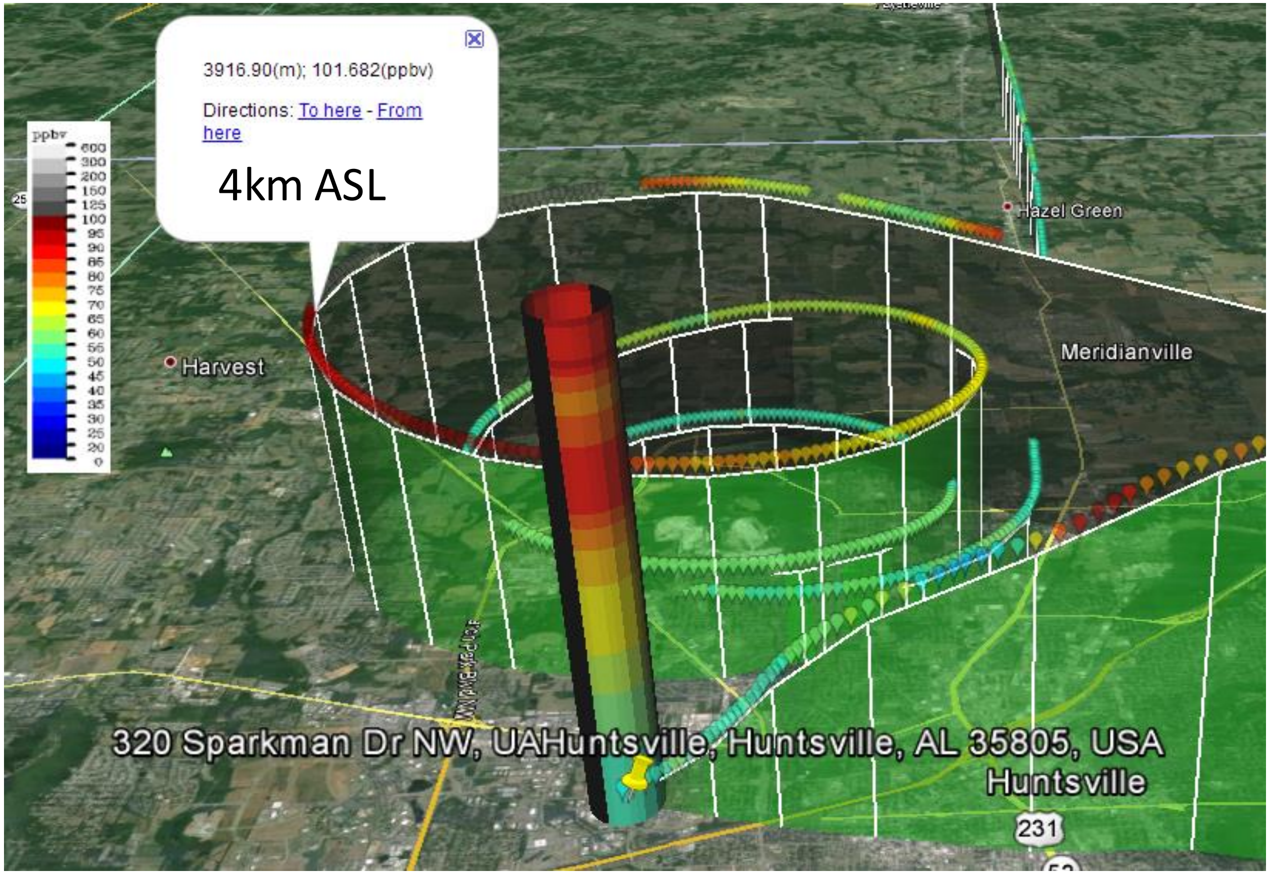
[*Wang et al.*, 2015]

4. Lidar Observations in Support of SEAC^{4}RS and SENEX



In support of the SEAC^{4}RS field campaign the UAH TOLNet lidar took nearly continuous O_3 observations during Aug.-Sep. 2013 (some example output shown above). During this time, the system observed numerous O_3 layers with enhancements associated with stratospheric transport and wildfires. The UAH 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.

4. Lidar Observations in Support of SEAC^{4}RS and SENEX



Comparison of the UAH O_3 lidar, UAH ozonesonde, and NOAA P3 aircraft measurements

In support of the SENEX field campaign the UAH TOLNet lidar took nearly continuous ozone observations during June 2013. During this time, the system took measurements in unison with the NOAA P3 airborne platforms and ozonesondes (example shown above). This data has been evaluated to investigate numerous processes impacting tropospheric O_3 (e.g., air pollution transport, stratosphere-troposphere exchange, impact of wildfires on O_3).

Supporting Information and Publications

Instrument description and retrieval algorithm

Kuang, S., J. F. Burris, M. J. Newchurch, S. Johnson, and S. Long (2011), Differential Absorption Lidar to measure subhourly variation of tropospheric ozone profiles, *IEEE Trans. Geosci. Remote Sens.*, *49*, 557-571.

Kuang, S., M. J. Newchurch, J. Burris, and X. Liu (2013), Ground-based lidar for atmospheric boundary layer ozone measurements, *Appl. Opt., 52*, 3557-3566.

Scientific analysis of lidar data

Wang, L., M. Cook, M. J. Newchurch, K. Pickering, A. Pour-Biazar, S. Kuang, W. Koshak, and H. Peterson (2015), Tropospheric ozone lidar data evaluation of the lightning-induced ozone enhancement simulated by the WRF/Chem model, *Atmos. Environ.*, 115, 185-191.

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