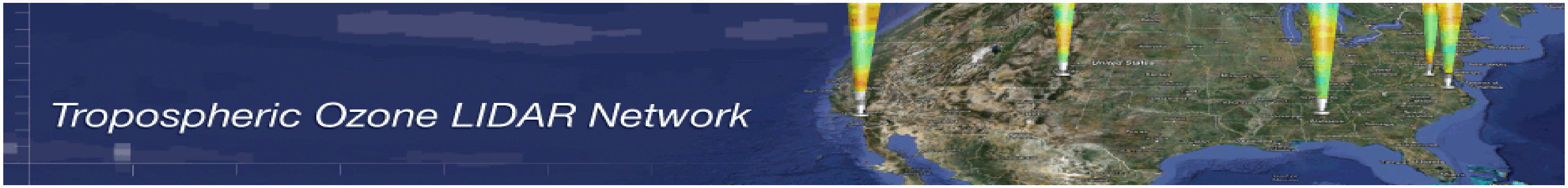

Tropospheric Ozone Lidar Network (TOLNet) –

Tropospheric Ozone and Aerosol Profiling for Satellite Continuity and Process Studies

AMS 93rd Annual Meeting, Austin, TX, Austin Convention Center room 18C
Jan. 9, 2013

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[1]UAHuntsville, [2]NOAA/ESRL, [3]NASA/HQ, [4]NASA/GSFC, [5]NASA/LaRC, [6]UMBC, [7]NASA/JPL, [8]NOAA/NESDIS, [9]USEPA,

http://nsstc.uah.edu/atmchem/

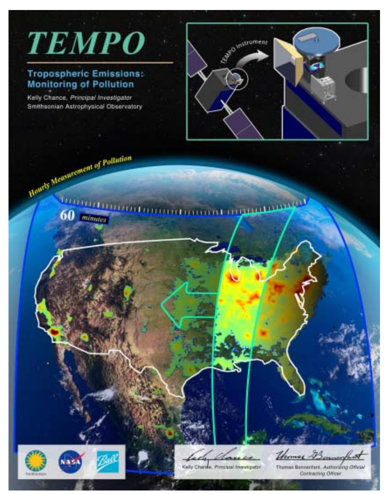
Motivation for lidar measurements

• **GEO-CAPE** and **TEMPO** will measure tropospheric gases and aerosols at ~8km and hourly resolution. **Vertical resolution is on the order of 5-10km** in the troposphere. This vertical resolution is inadequate to resolve laminar structures that characterize tropospheric ozone and aerosols. Furthermore, GEO-CAPE information content in the **PBL will likely be inadequate** to resolve the processes responsible for air quality variability. We seek, therefore, to **augment the spaceborne measurements** with a ground-based measurement system.

• **Ozonesondes** are used extensively in various atmospheric chemistry studies because of their low upfront cost and well-characterized behavior. However, the whole process for a sonde launch typically requires four hours. And **four-hour ozonesonde resolution is prohibitively expensive**. We therefore consider **lidars** to provide the necessary spatial and temporal resolution.

UAH ozonesonde

Three major O3 profiling techniques



JPL-Table Mountain Facility
http://tmf-lidar.jpl.nasa.gov/index.htm

TOLNet Objectives

(1) Provide high-resolution, time-height measurements of ozone and aerosols at a few sites from near surface to upper troposphere for air-quality/photochemical model and satellite retrieval validation.

(2) Exploit synergies with EV-I/TEMPO, DISCOVER-AQ, GEO-CAPE, and existing networks, including regulatory surface monitors and thermodynamic profilers, to advance understanding of processes controlling regional air quality and chemistry;

(3) Develop recommendations for lowering the cost and improving the robustness of such systems to better enable their possible use in future national networks to address the needs of NASA, NOAA, EPA, and State/local AQ agencies.

NOAA Mobile Ozone Lidar

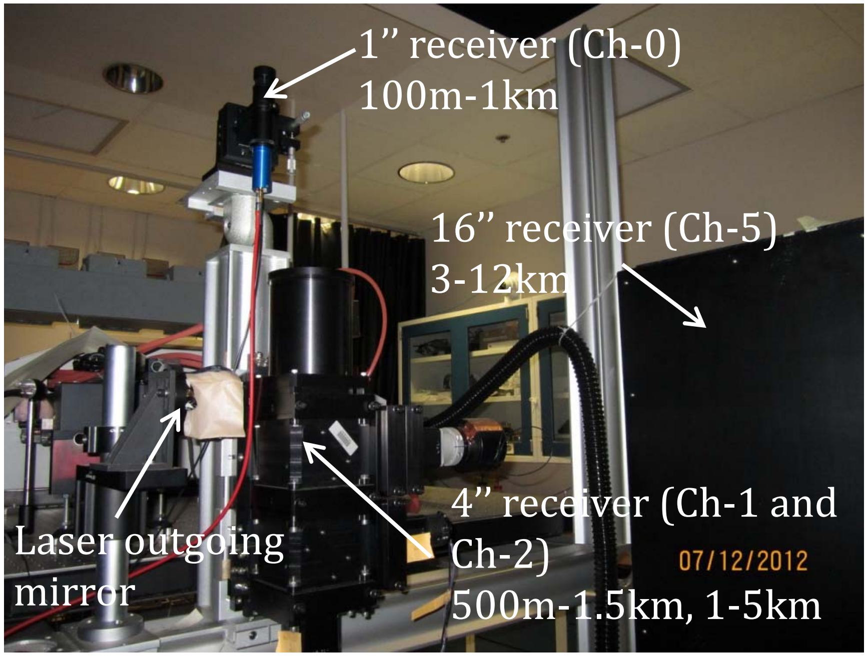
NOAA's **TOPAZ** (Tunable Optical Profiler for Aerosol and oZone) lidar is a state-of-the-art, compact differential absorption lidar (DIAL) for measuring ozone profiles with high temporal and spatial resolution (Alvarez et al., 2011). The instrument is based on a Nd:YLF pumped Ce:LiCAF ultraviolet laser. TOPAZ emits **three wavelengths**, that can be **tuned** from approximately 283 nm to 310 nm. Ozone profiles are typically retrieved at a range resolution of **90 m**. Time resolution varies from **10 s** to several minutes depending on the atmospheric conditions and the desired precision of the data.

Originally designed for airborne operation, the TOPAZ lidar was installed in a truck in January 2012 to permit easy transport to and operation at remote sites (Fig. 1). A **two-axis scanner** mounted on the roof of the truck permits pointing the laser beam at several shallow elevation angles at a fixed, but changeable azimuth angle. Zenith operation is achieved by moving the scanner mirror out of the laser beam path. By using the scanner to vary the elevation angle, high resolution ozone measurements can be obtained to **within 15 m of the surface**. Horizontal measurements at different azimuth angles can be performed to study the variability of ozone near the surface.

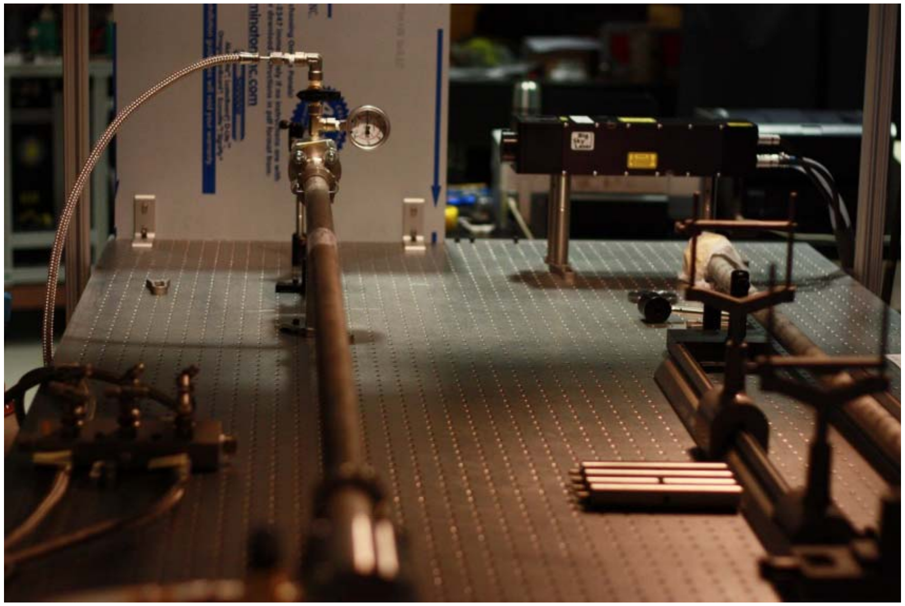
Fig. 1 Truck-based, scanning TOPAZ lidar at the 2012 Uintah Basin study.

UAHuntsville Ground-based O3 lidar

The **UAHuntsville** O3 lidar system was developed jointly by UAHuntsville and NASA/GSFC [*Kuang et al*., 2011a]. (**Left**) Receiver system showing the recent added 1'' mini receiver to measure ozone between 100 and 1000m altitude; (**Right**) Raman shifted YAG transmitter replacing previous dye lasers. Located at a 200-m ASL slightly polluted city, this lidar makes ozone retrieval from 0.1 to ~12 km during both daytime and nighttime with a typical integration time from 2 to 10 min.

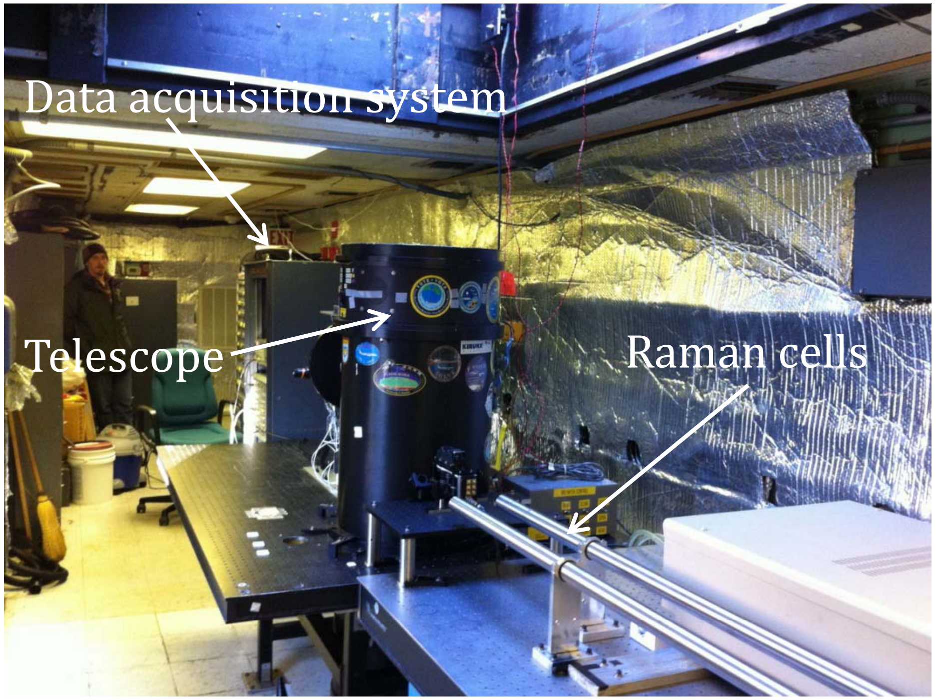


Receivers



Transmitter

NASA/GSFC Mobile lidar



View from inside the 40’ trailer.

The trailer with the hatch doors open for transmission into the atmosphere.

Moving from left to right: the rack for the data acquisition system; the optics module package that houses the narrow band interference filters for the PMT’s, the chopper attached to the telescope, which helps eliminate saturation of the PMT’s; the transmission platform for two 1’’ detectors is mounted directly next to the 18’’ telescope for the near-ground ozone measurements. The two 72’’ Raman cells mounted on the table produce 289 and 299-nm lasers using pressurized hydrogen and deuterium.

NASA/LaRC Mobile lidar

NASA Langley is developing an ozone lidar in a trailer that can be easily deployed at locations throughout the U.S. The lidar will produce tunable on and off ozone DIAL laser wavelengths between 280 and 300 nm at 500 Hz each. There is also a 527 nm aerosol channel. The system has an in situ ozone measurement capability which will allow ozone to be profiled from the ground to the lower troposphere.

PBL Ozone Measurements

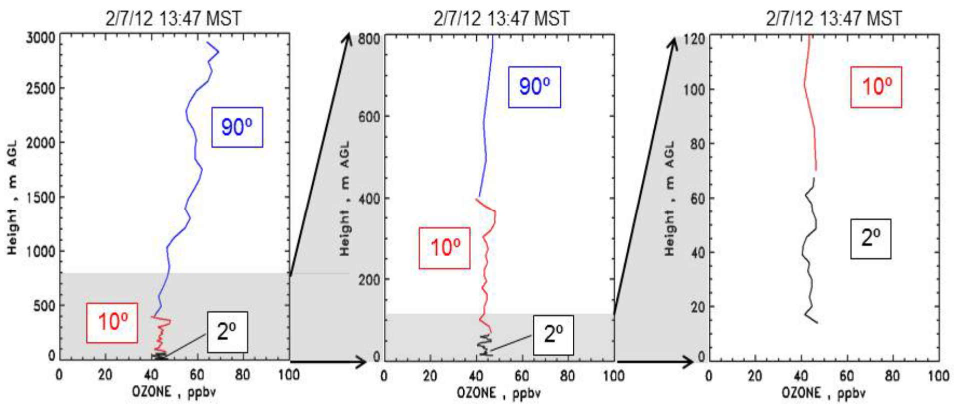


Fig.2: Lidar ozone profiles at 2, 10, and 90 degrees elevation, projected vertically and blended together. Each panel shows the same composite profile, expanded form left to right to show the detail in the lower angle measurements close to the surface.

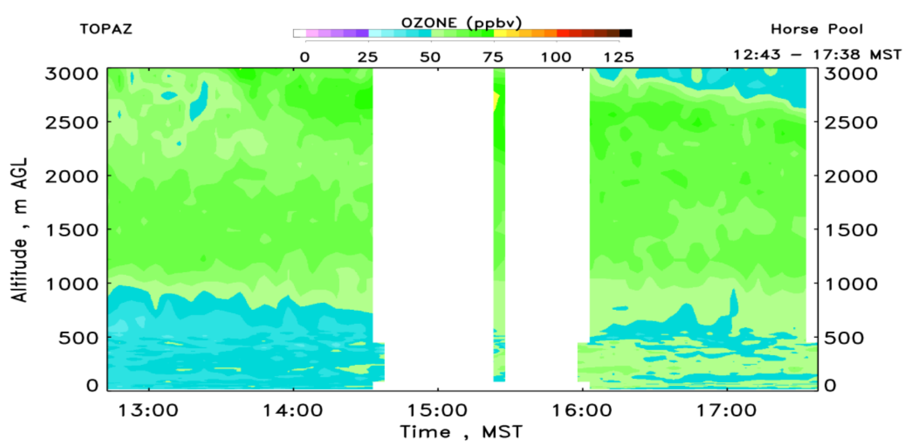
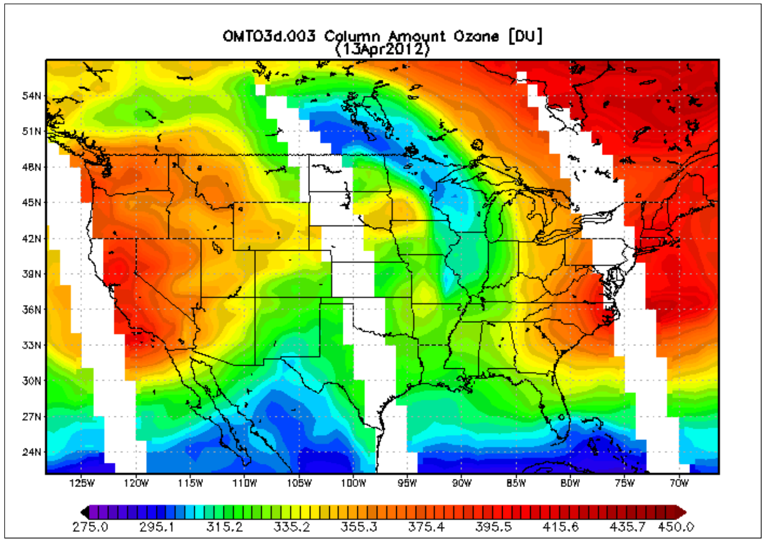


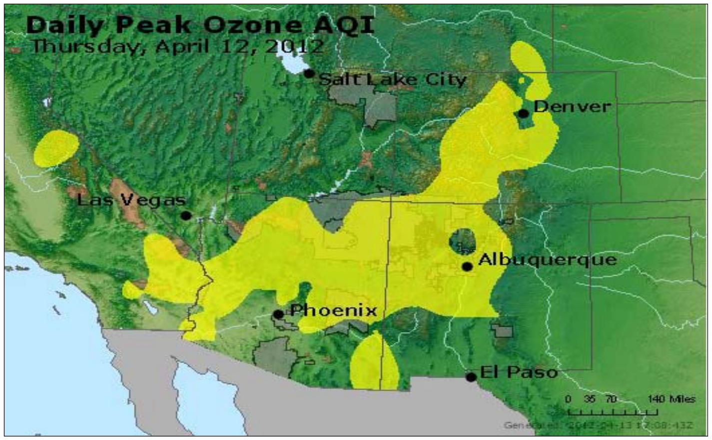
Fig. 3: Time height cross section of composite vertical O_3 profiles from 15 m to 3 km AGL.

The truck-based **TOPAZ** lidar was deployed in the February 2012 **Uintah Basin** study to investigate high wintertime ozone levels observed in the oil and gas fields of northeast Utah. Because very shallow boundary layers created by stable conditions are thought to be a contributing factor to the high ozone, lidar observations were made using elevation angle sequences of 2, 10, and 90 degrees, that were repeated approximately every five minutes. The ozone profiles measured at these three angles are spliced together to create composite vertical profiles **extending from 15 m to about 3 km AGL** (Fig. 2). The effective **vertical resolution** of the composite ozone profiles increases with altitude from **3 to 90 m**. The ozone time-height cross section in Fig. 3 shows a descending elevated ozone layer that appears to get **mixed down to the surface** in the late afternoon.

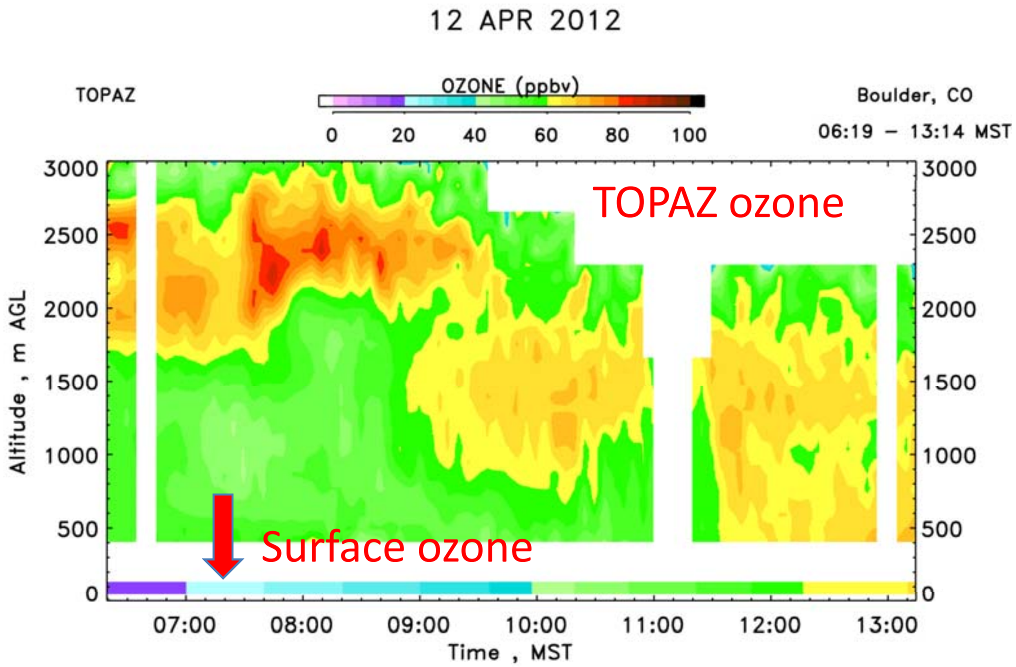
Alvarez, R.J., II, et al. : Development and Application of a Compact, Tunable, Solid-State Airborne Ozone Lidar System for Boundary Layer Profiling, *J. Atmos. Oceanic Technol.,*28, 1258-1272, 2011.

TOPAZ obs in Boulder: STT on 12 April 2012

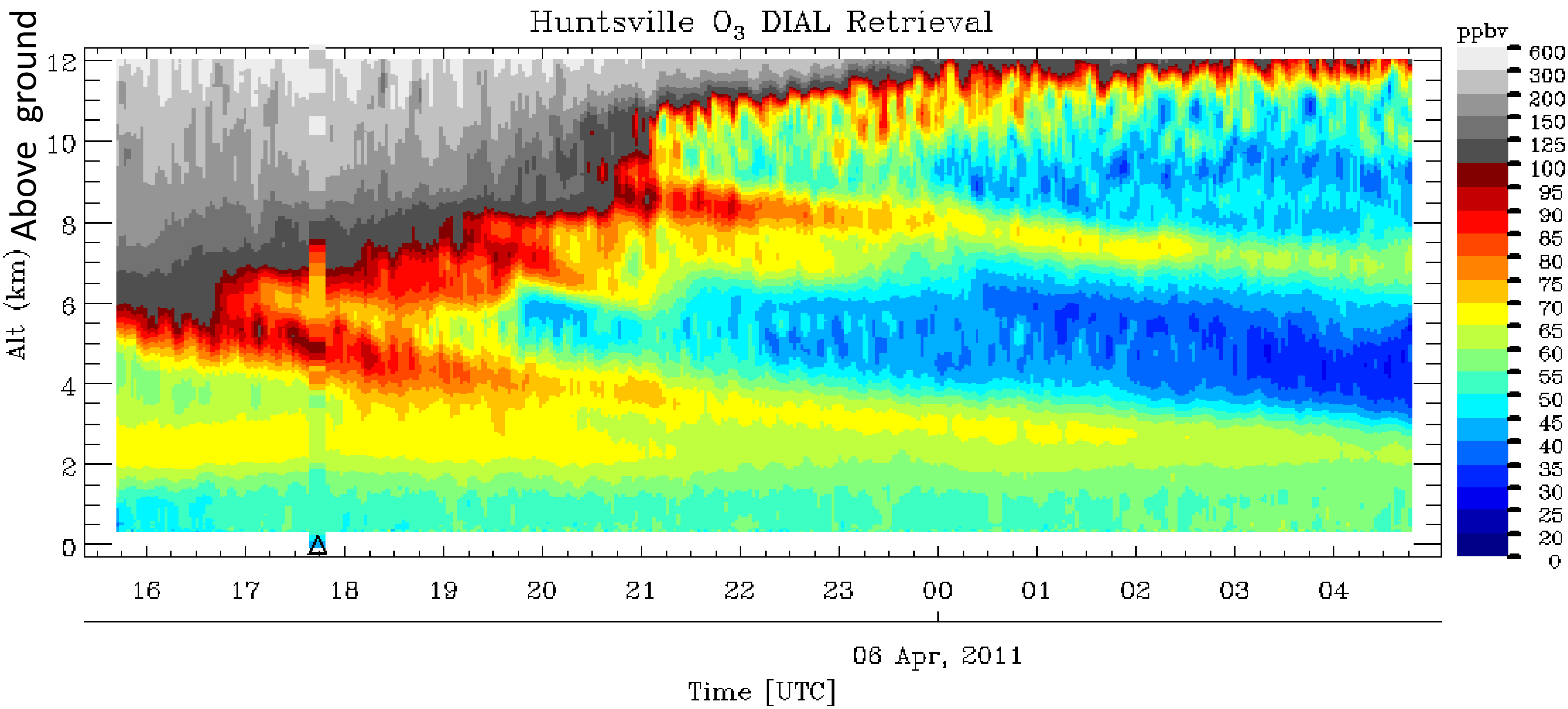




From compilation by Pat Reddy

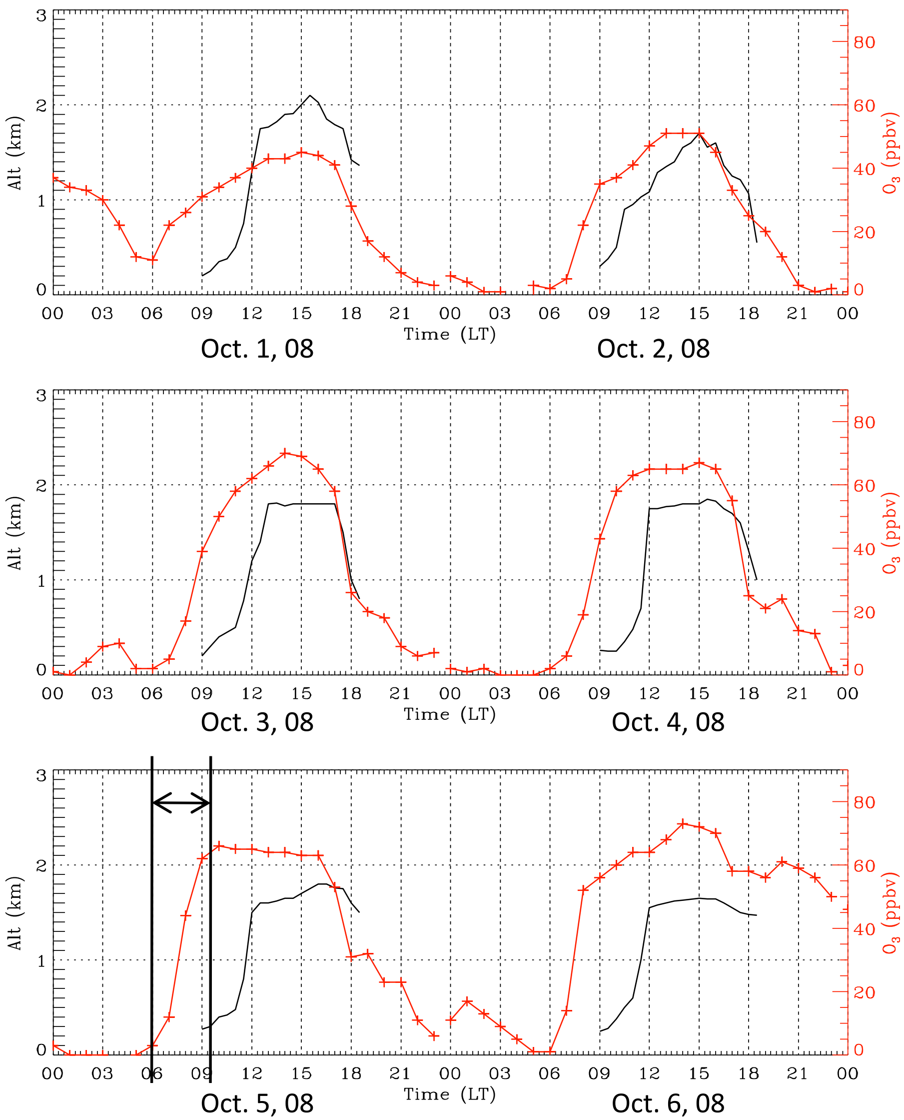


An example of O3 Lidar measurement with 2-min resolution

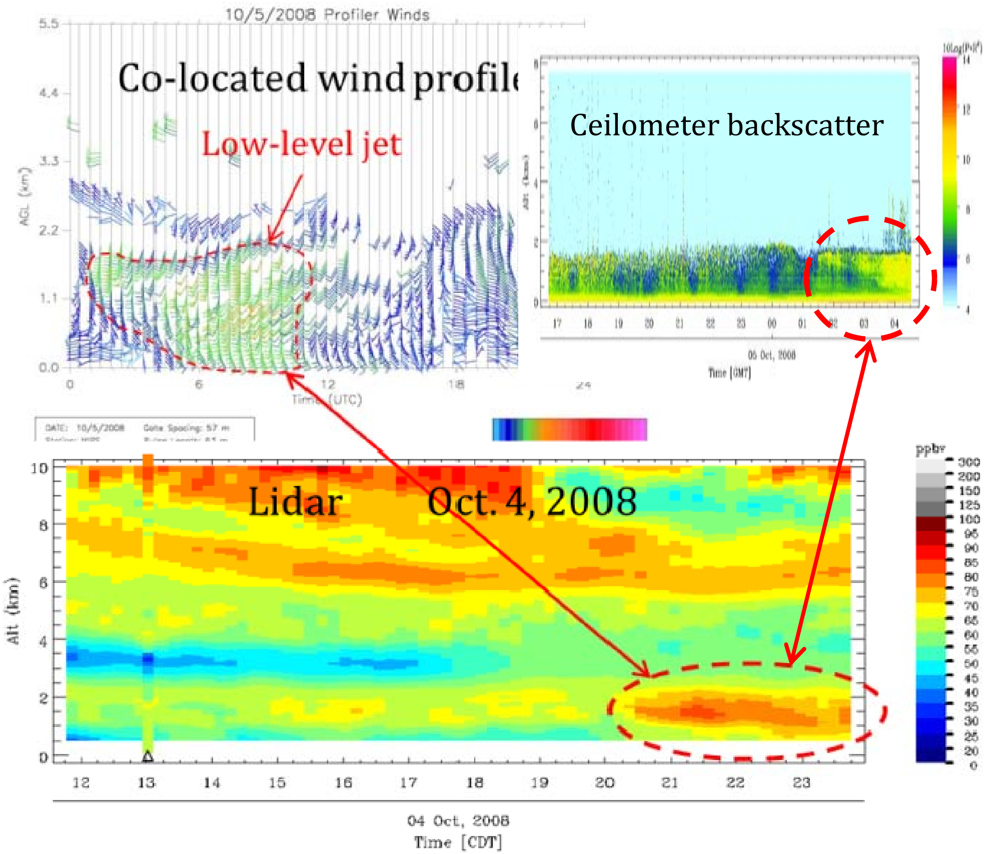


O3 Transport through Low-level Jet

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



Surface O3 and convective boundary layer height



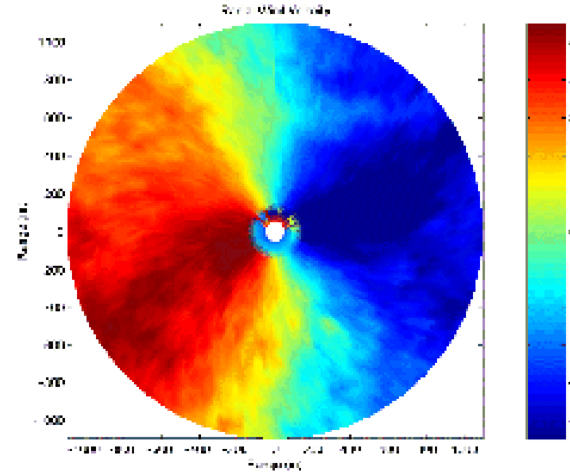
Higher increasing rate of the surface O3 before 10AM on Oct. 5 due to the low-level transport on the previous day

[*Kuang et al.*, 2011b]

UAH Collocated Wind Measurement for the O_3 Flux Calculation

Specifications

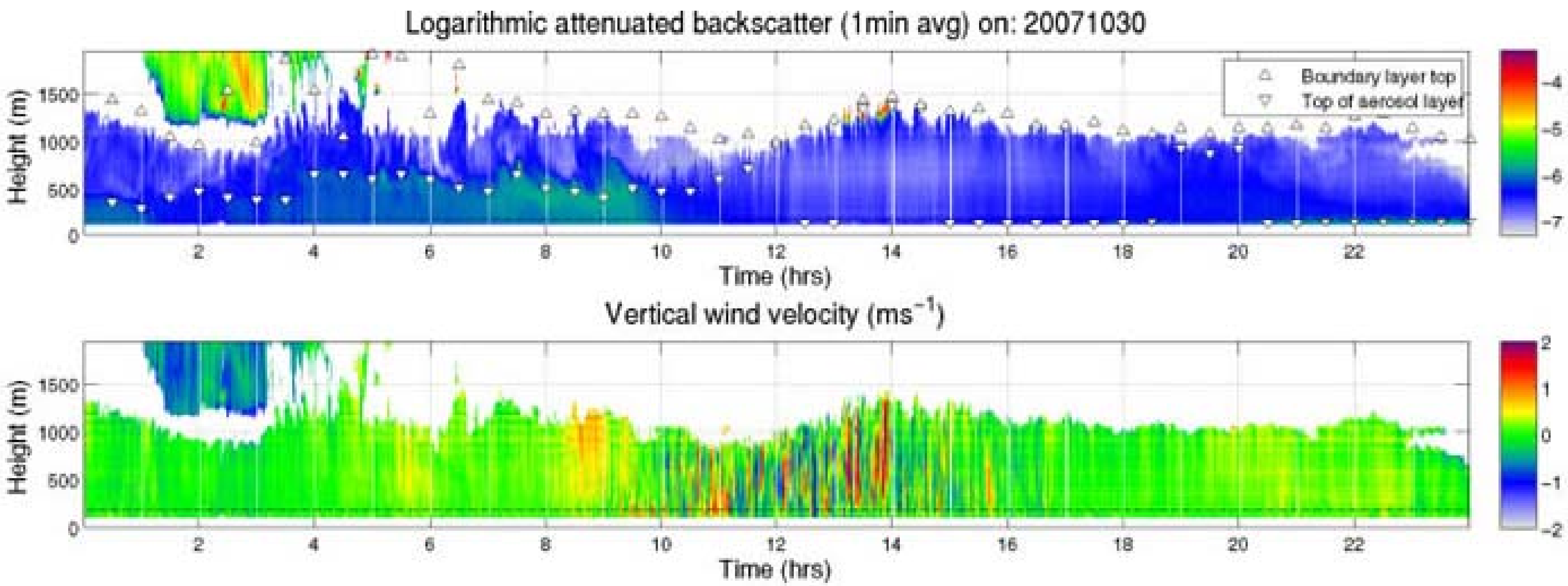
l = 1.55 mm
Pulse energy: 10 mJ
PRF: 15 kHz
Pulse length: 150 ns
Gate spacing: 10-50 m
Min/max range: 75 m to 10 km
Telescope diameter: 75 mm
Divergence: 50 mrad



PPI, 10 elevation, 1 km range
Radial velocity every 23 s

Halo Doppler wind lidar

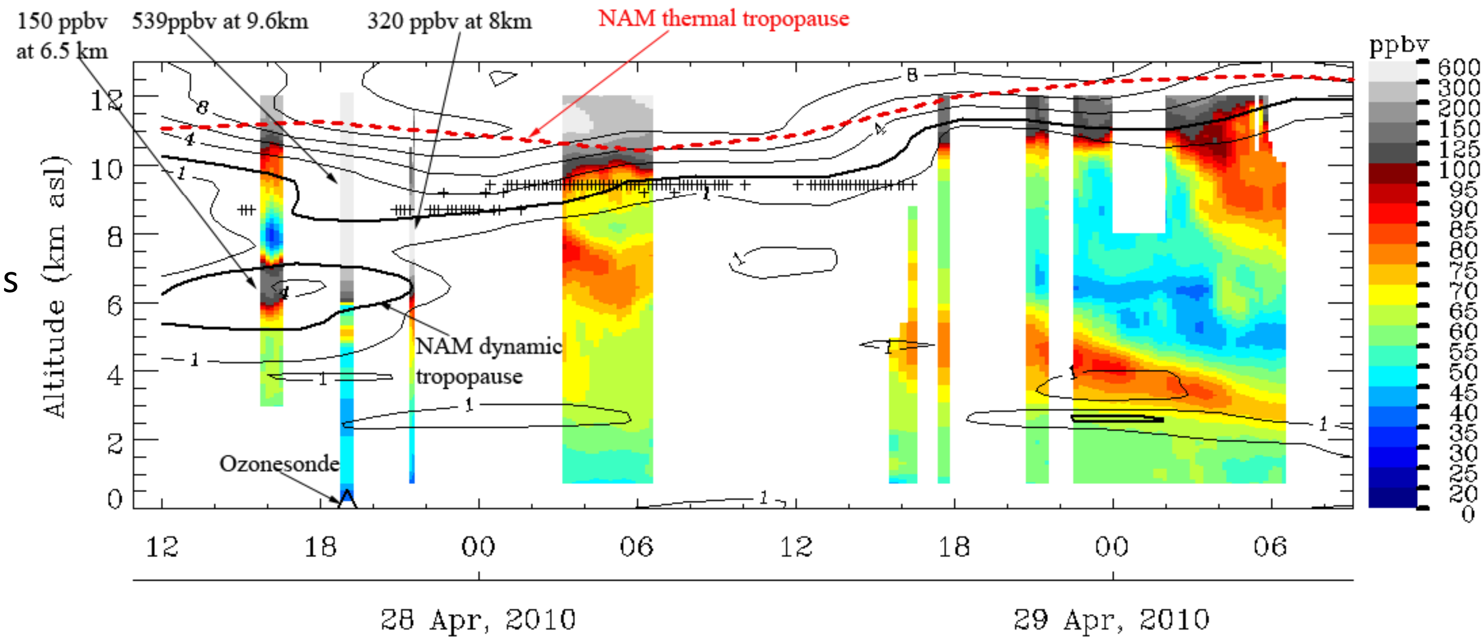
Vertically-pointing measurements depict boundary layer structure and evolution

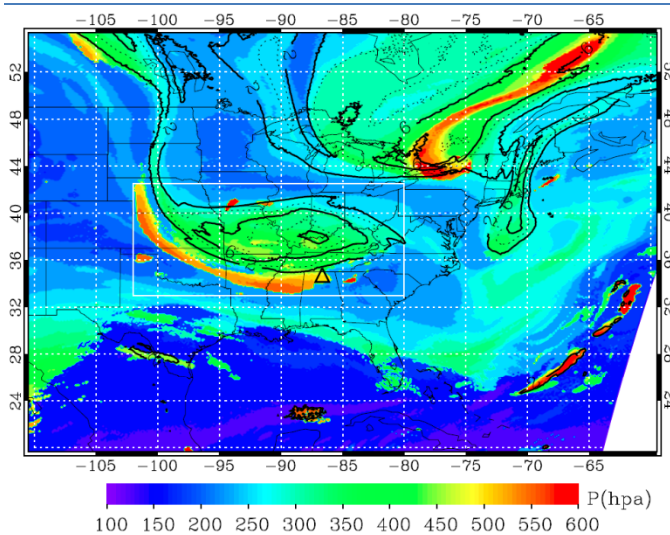


Stratosphere-to-Troposphere Transport

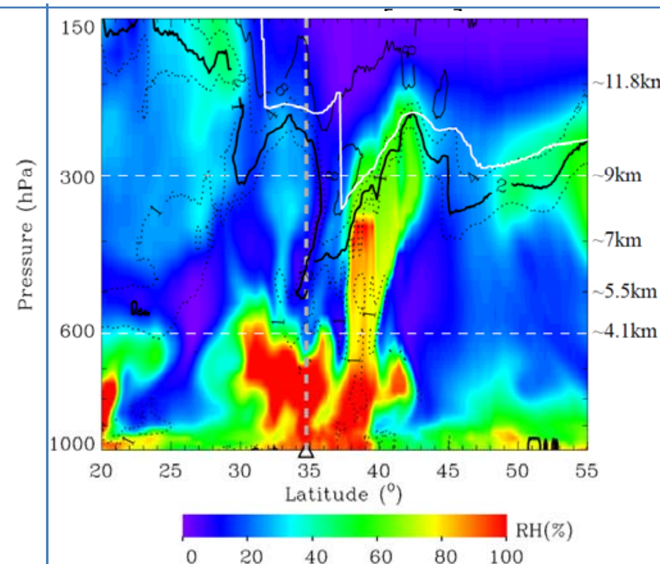
[*Kuang et al.* 2012 JGR]

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



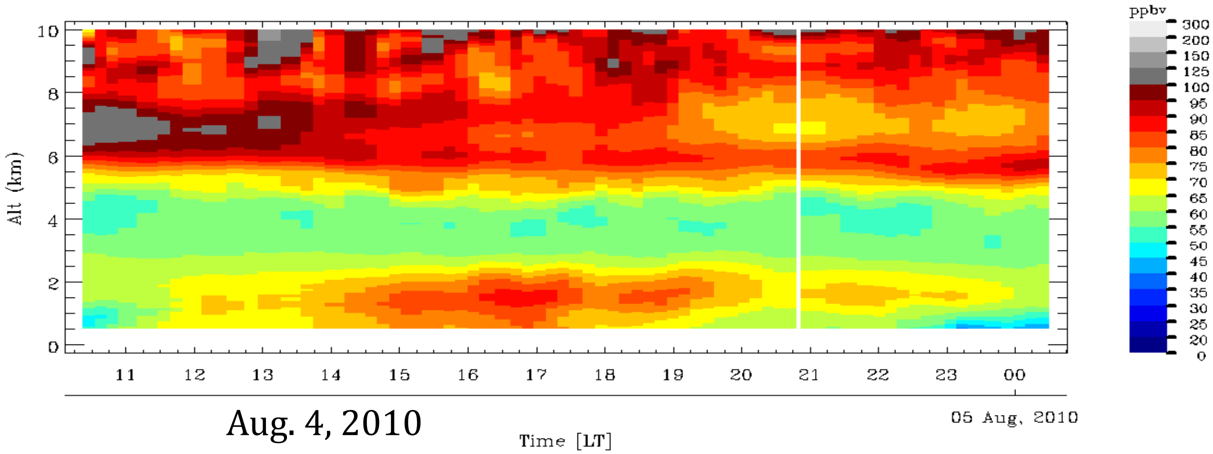


IPV at 320-K isentropic surface

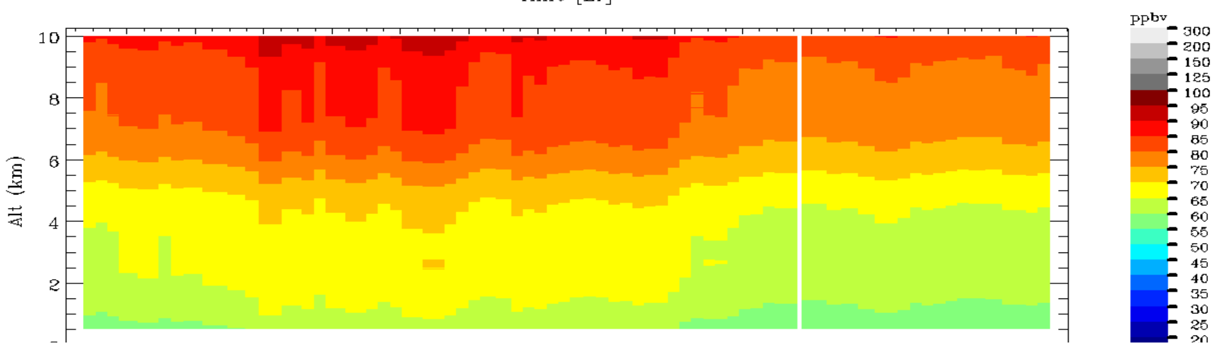


Pressure-latitude cross-section of **PV** (black lines), **RH** (color contours), and tropopause pressure, at 86.65°W longitude at 1200 UTC 27 April 2010 derived from the NAM model.

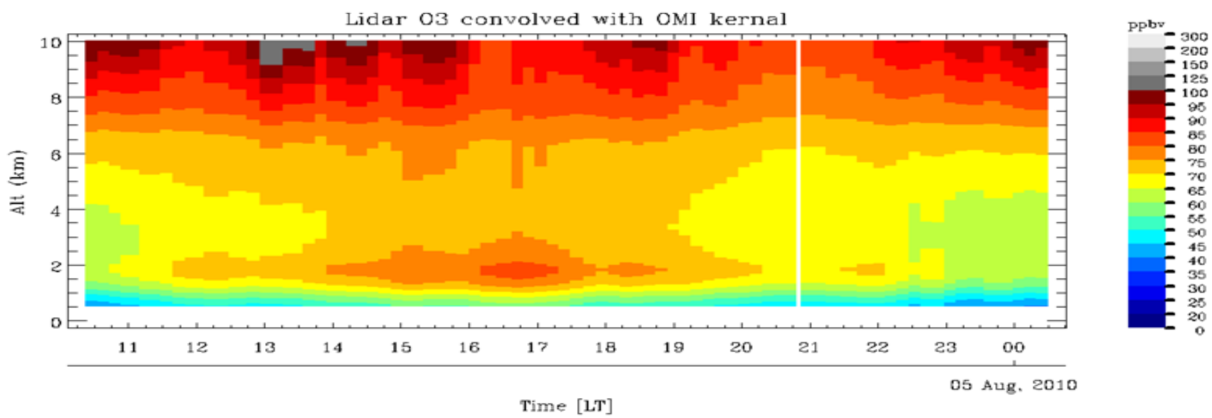
Comparison of the true atmosphere with expected OMI obs



Lidar observation showing large PBL O3 diurnal variations

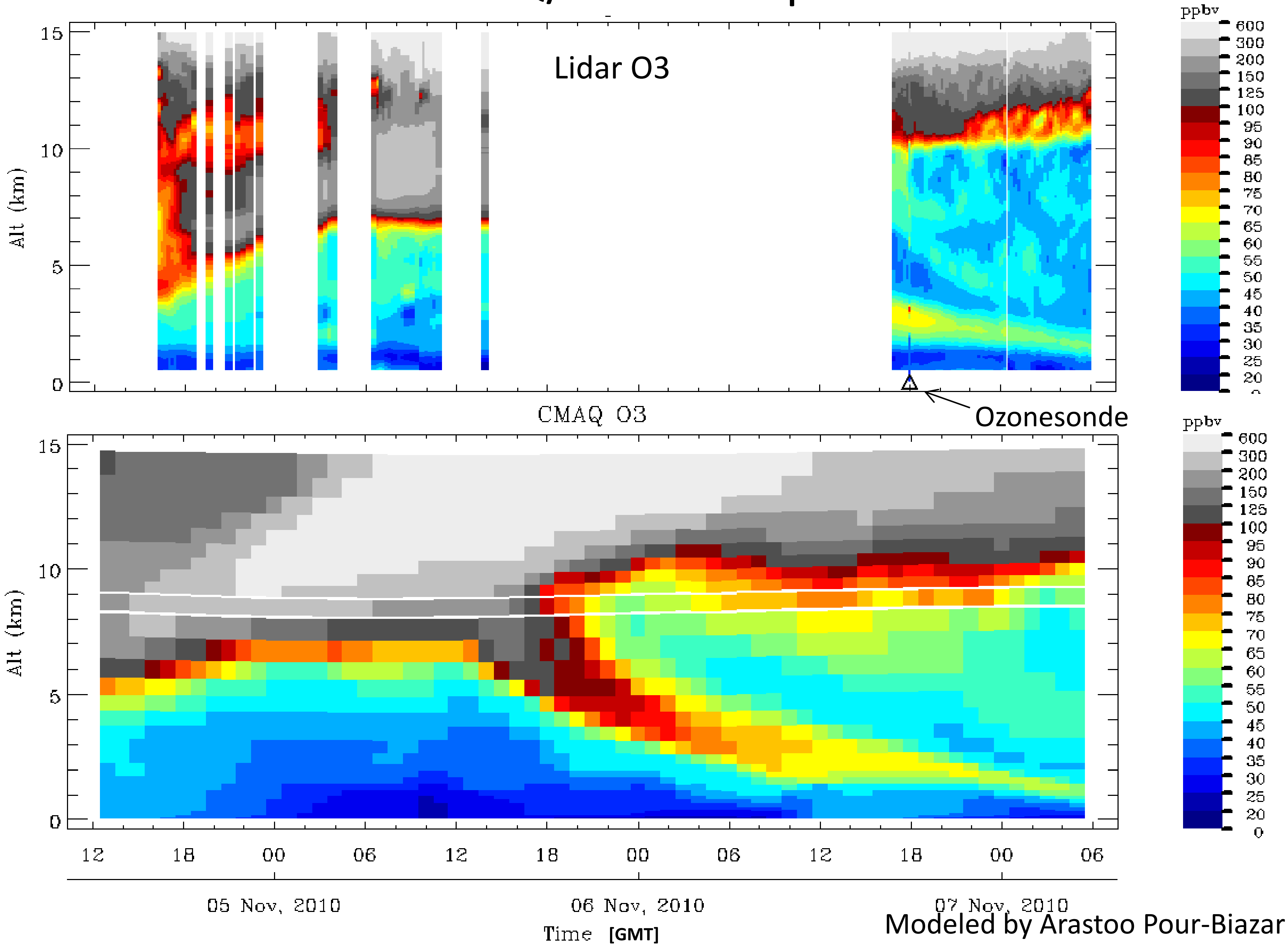


Lidar convolved with OMI **UV** kernel (24 layers): OMI is unable to caputre the highly variable ozone structure in PBL because of its resolution limitation.



Lidar convolved with OMI **UVVIS** kernel (69 layers) Similar to expected TEMPO capability.

WRF-CMAQ/Lidar Comparison of STE Event



Modeled by Arastoo Pour-Biazar

4. Data Access

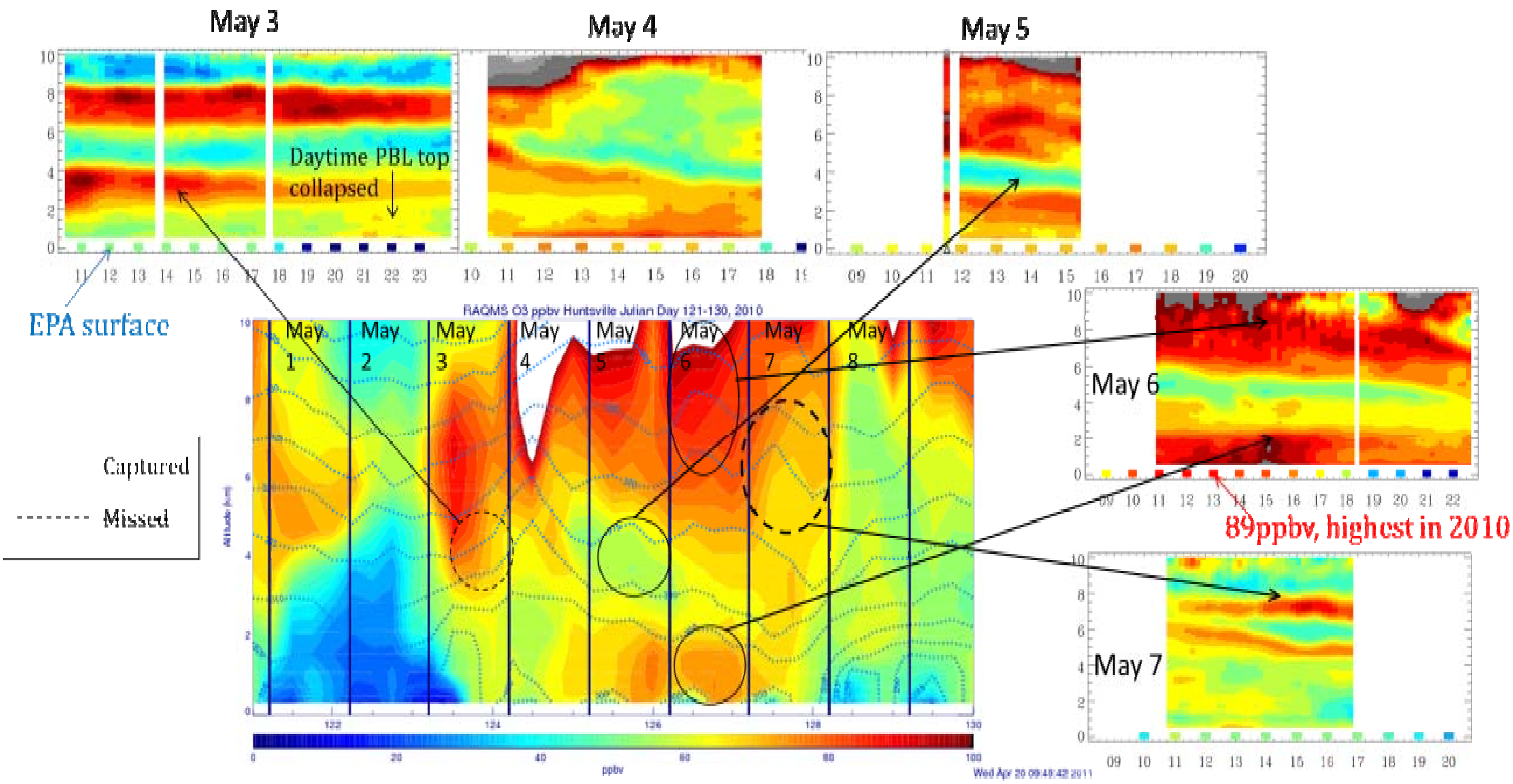
http://www-air.larc.nasa.gov/missions/TOLNet/

5. Summary and Future Plans

1. TOLNet development aims at long-term O3 and aerosol profiling for satellite validation and process studies.
2. The lidar measurements at multiple sties will be used to study the impact of ozone aloft on surface ozone over a diverse range of air-quality environments; evaluate air quality models to improve their simulation and forecasting capabilities; provide high time-resolved observations to begin preparing for TEMPO and GEO-CAPE satellite missions.
3. Leveraging current instrumentation and expertise provides a cost-effective way to obtain these research observations.
4. In 2012, we have accomplished most of the hardware development, such as transmitter and receiver upgrade, and mobile platform construction.
5. In 2013, we plan to make more frequent observations, validate the PBL retrievals with tethered ozonesonde, investigate regional pollution transport using multiple-station lidar data, and support other field campaigns (e.g., DISCOVER-AQ) with mobile lidar.
6. We invite collaborations with all interested investigators

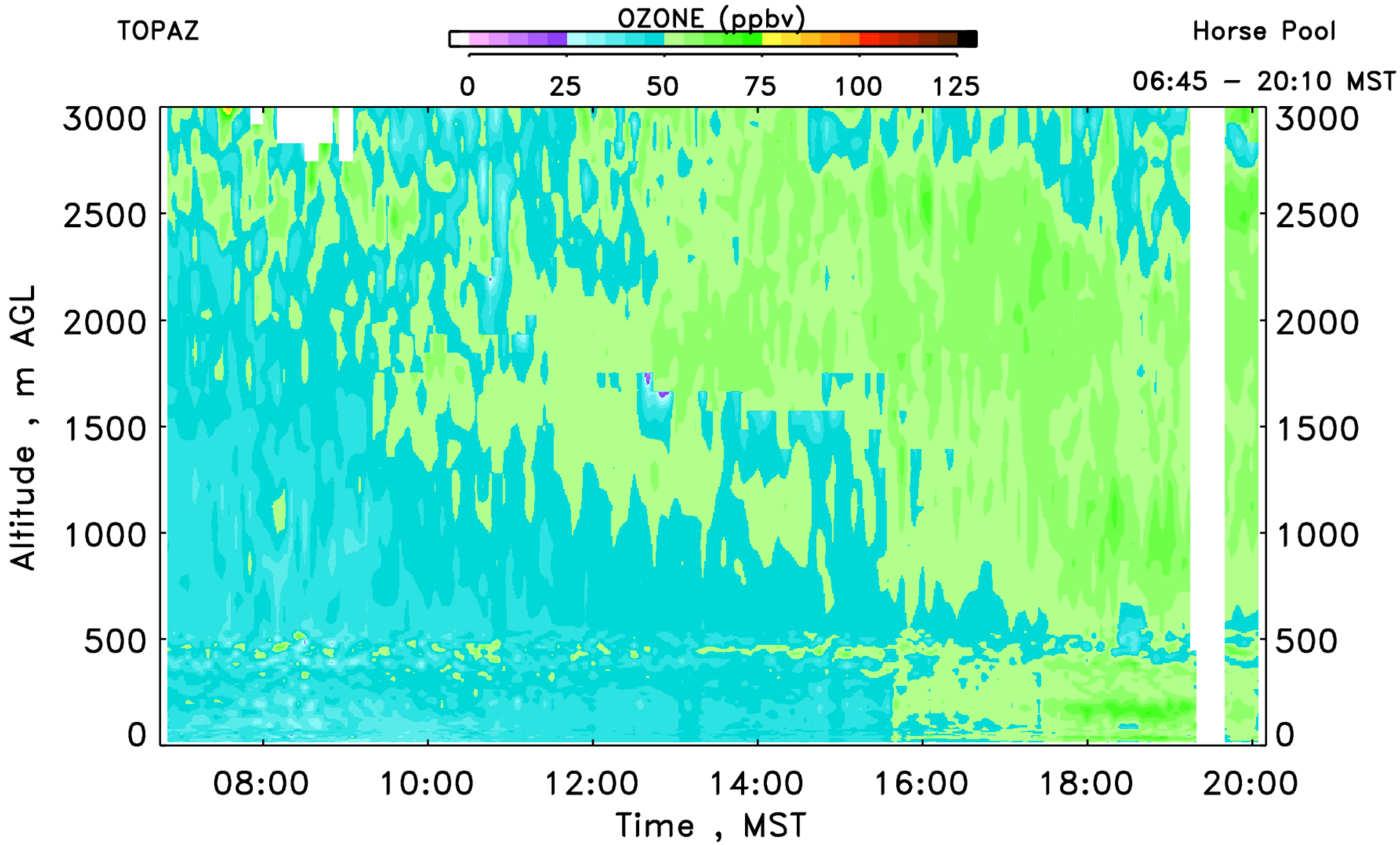
Funding Support

Comparisons of lidar observations and RAQMS model simulations for 3-7 May 2010 (modeled by Brad Pierce)

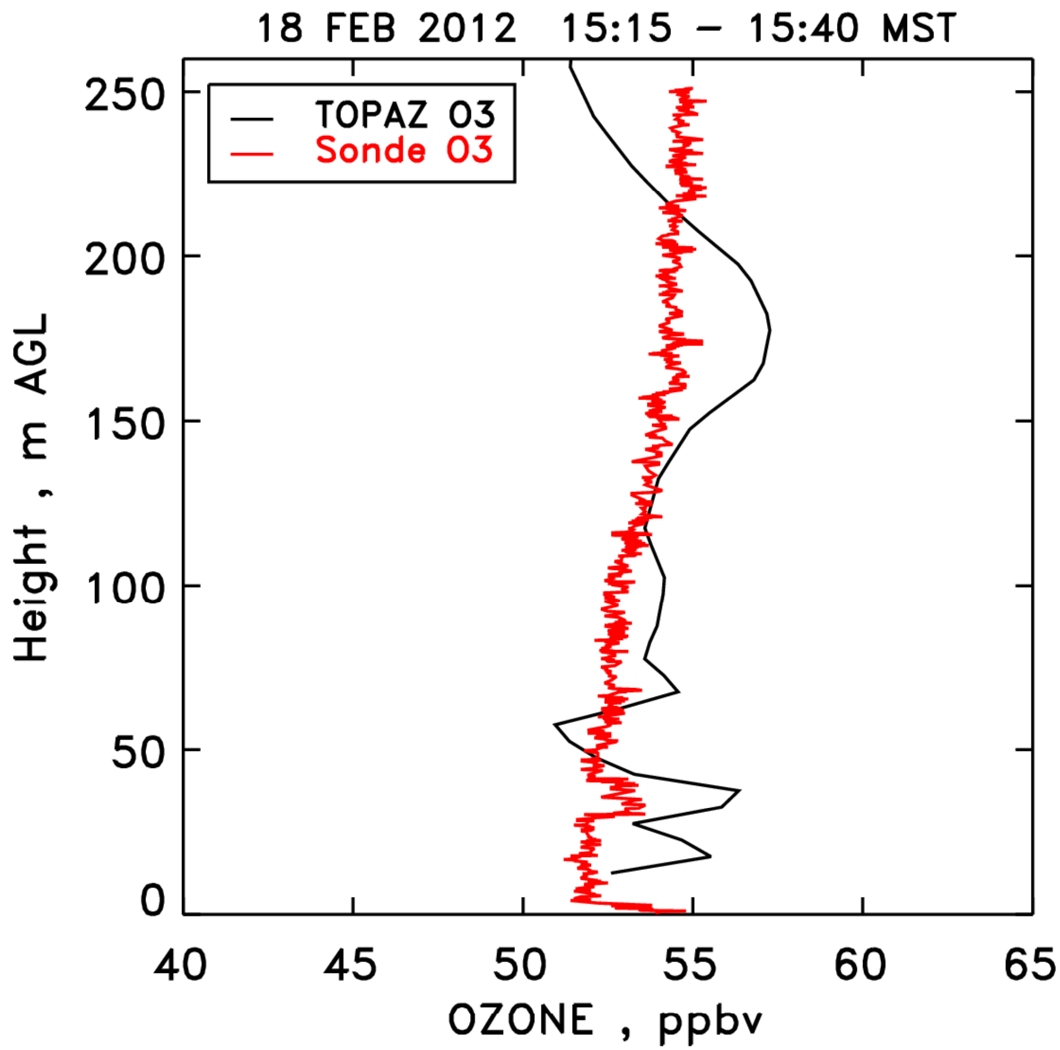


UBWOS 2012: TOPAZ composite O_3 profiles: 06 – 29 Feb

(62 hours of data collected on 14 days)



UBWOS 2012: TOPAZ O_3 profile comparison w/tether sonde



O_3 sonde data provided by B. Johnson, P. Cullis, E. Hall, D. Helmig