RECONFIGURATION OF THE NOAA TOPAZ LIDAR FOR GROUND-BASED MEASUREMENT OF OZONE AND AEROSOL BACKSCATTER

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ABSTRACT

The NOAA Tunable Optical Profiler for Aerosol and oZone (TOPAZ) lidar is a differential absorption lidar (DIAL) for measuring ozone concentration and aerosol backscatter profiles that was originally designed for nadir-looking operation from an airborne platform. In order to expand the capabilities of this system, we have reconfigured the TOPAZ system for ground-based zenith-looking operation and have constructed an optical scanner to allow measurements at low pointing angles (0-30 degrees). In this new configuration, TOPAZ is capable of making measurements from ground level to several kilometers altitude with high vertical resolution near the ground. The (reversibly) reconfigured system has been installed in a truck and was deployed to the Uintah Basin Winter Ozone Study (UBWOS) experiment in eastern Utah, USA. The TOPAZ lidar modifications and the new scanner are described, and data acquired in this new configuration are presented.

1. BRIEF LIDAR DESCRIPTION

The NOAA TOPAZ lidar [1], [2] is designed around an all solid state Ce:LiCAF-based laser which is tunable from 285-310 nm. The system is operated with three output wavelengths tuned sequentially on a pulse-to-pulse basis to provide the signals needed for a DIAL measurement of ozone profiles along with aerosol backscatter profiles. The pulses are ~100 ns wide, the pulse rate is 1000 Hz, and the combined output of the three wavelengths is ~100 mW. The laser beam is transmitted coaxially with the receiver telescope.

The receiver portion of the lidar uses a 0.5 m diameter telescope to collect the backscattered light and photomultiplier tubes for detection in two channels (near-field and far-field). The signals from these two channels are digitized and accumulated in a custom field programmable gate array (FPGA)-based data acquisition system. The digitized signals are then saved to disk and processed using a first-cut analysis for real-time display to the lidar operators.

An iterative DIAL analysis technique was developed for this system to calculate the ozone and aerosol profiles and to remove effects on the ozone profiles due to differential aerosol backscatter and extinction.

In its airborne (nadir-looking) configuration, TOPAZ is capable of measuring ozone with 90-m and 10-s resolution along the lidar line-of-sight with <5% typical and up to 15% accuracy [2] depending on the total atmospheric attenuation along the measurement path. Uncalibrated aerosol backscatter profiles are measured with 18-m resolution for the same 10-s interval. For both measurements, the profiles start ~400 m from the lidar (limited by transmitter-to-receiver overlap) and can extend up to 5000 m range.

Significantly more details of the airborne configuration of the TOPAZ lidar and the analysis of its signals may be found in [1] and [2].

2. RECONFIGURATION FOR GROUND-BASED OPERATION

In order to expand the deployment capabilities of the TOPAZ lidar, it was decided to modify the system so that it can be operated from a ground-based platform. (To date, all of the modifications to the TOPAZ lidar have been reversible so that capability for future airborne deployments is retained.) The new configuration is a truck-mounted, zenith-looking lidar which can be coupled with an optical scanner to allow for pointing at low elevation angles. The scanning capability addresses two problems that would occur if the lidar was simply re-designed to be a zenith-looking system. First, as mentioned above, the lidar has a ~400 m minimum measurement range. Scanning to low angles allows measurements to be made essentially to ground level. Second, the low-angle data has an effective vertical resolution much smaller than the 90 m (line-of-sight) resolution of the lidar, so that details in the lowest levels of the boundary level can be resolved.

To implement the new configuration, the receiving telescope was inverted to look upward through a port in the ceiling and a scanner was designed and built to mount on top of the truck over the lidar. The scanner can be pointed (manually) to any azimuth relative to the truck, and the motor-driven elevation axis allows automated direction of the lidar beam from 0 to +30 degrees relative to the horizon as well as moving the mirror out of the beam to allow zenith measurements. Figures 1 and 2 show the reconfigured TOPAZ system and its truck-based deployment with scanner respectively. The mirror currently mounted in the scanner is a smaller mirror than is needed to accommodate the full aperture of the lidar (0.5 m diameter). This temporary substitution was necessary due to the limited time available to acquire the full-sized mirror that will ultimately be installed in this scanner.

With the new configuration, several modifications were required in the computer control and processing software. First, software was developed to control the scanner including motor drive parameters, angle feedback, and synchronization of the data acquisition with the scanner position. Secondly, the data analysis software was modified to incorporate the effect of the various pointing angles on the calculation of the ozone concentration and aerosol backscatter profiles. Finally, the integration (splicing) of the profiles from the various angles into a single profile extending from ground level to the maximum range of the zenith profiles was implemented in post-processing.

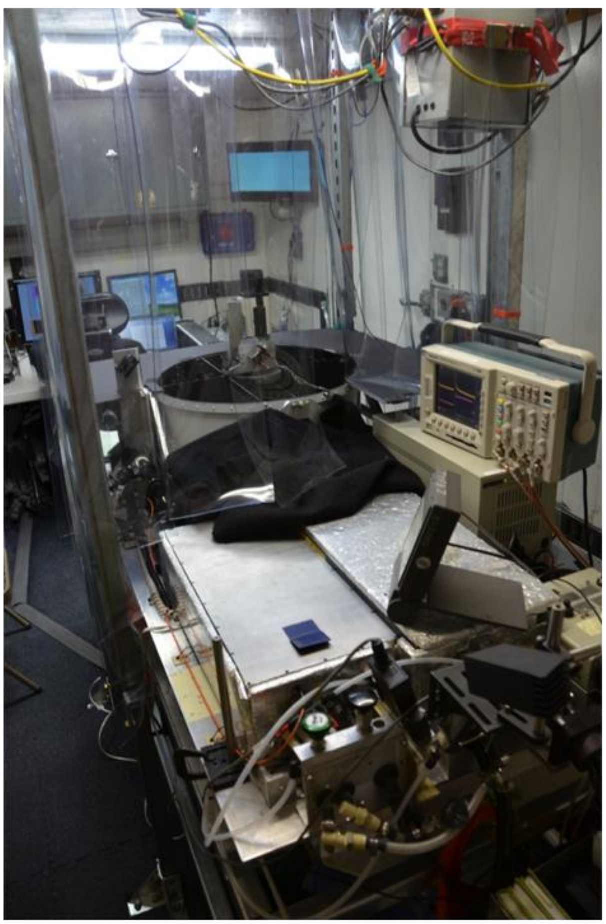

Figure 1. The TOPAZ lidar system reconfigured with up-looking telescope and installed in its truck platform.

Figure 2. a) TOPAZ deployed at the UBWOS experiment. b) Detail of scanner.

3. GROUND-BASED DEPLOYMENT OF TOPAZ

The TOPAZ lidar was deployed to eastern Utah, USA, during February 2012 to participate in the Uintah Basin Winter Ozone Study (UBWOS, http://esrl.noaa.gov/csd/tropchem/2012ubwos/) in conjunction with numerous other instruments. The focus of this experiment was to gain a better understanding of the mechanisms that lead to the occasional wintertime incidences of high ground-level ozone that have been observed in certain areas of the western United States where gas and oil drilling is taking place. Since lower tropospheric ozone pollution is generally regarded as a summertime issue, its occurrence during winter with conditions of low temperatures, reduced insolation, and snow-covered ground (all of which are counter to the typical conditions associated with lower tropospheric ozone formation) is unexpected and not well understood. As these conditions are also typically associated with shallow boundary layers, it was necessary to be capable of profiling the layers closest to the ground with better resolution than could be done with TOPAZ from either an airborne platform or a zenith-only configuration while still maintaining the ability to profile altitudes above this shallow boundary layer. This requirement was met by implementing the low-angle scanning described above.

The scanning strategy used for the UBWOS experiment was to make measurements with the lidar pointed at each of three angles (2, 10, and 90 degrees relative to the horizon) for 75 seconds each. These longer averaging times (relative to the airborne operation) were used to help offset the higher signal noise due to a) reduced signals caused by faster drop-off of total (aerosol and molecular) backscatter when looking up, b) increased background light intensity, and c) reduced signals when scanning at low elevation angles caused by mirror losses and the smaller mirror currently installed in the scanner. With the time to move the scanner included, this sequence of data acquisition was repeated approximately every 5 minutes. The resulting groups of three profiles can then be spliced together to produce continuous profiles from ground level to the maximum lidar range with very high resolution near the ground and the original 90 m lidar resolution aloft. An example of a composite profile is shown in Figure 3, and a time-height cross section of these profiles is shown in Figure 4.

4. SUMMARY

While the high ozone conditions that were expected did not occur during the UBWOS experiment due to an unusually warm and dry winter in the study area, the initial deployment of the ground-based TOPAZ instrument was successful. The reconfigured hardware and software were tested, debugged, and operated during the study, and the flexibility of the modified TOPAZ lidar system has been demonstrated.

Additional measurements are planned in the areas in and around Boulder, Colorado, USA, and the further development of this instrument is expected to include

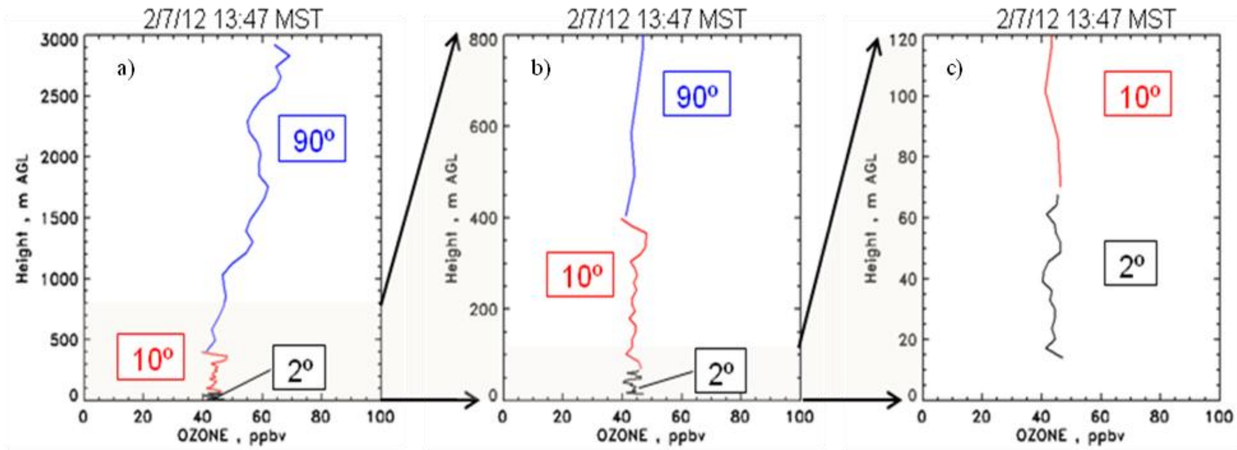

Figure 3. Composite profile of ozone concentration from the UBWOS field experiment. a) Entire profile (15-3000 m above ground level) with each segment labeled according to the lidar pointing angle that the data is derived from. b) The lowest 800 m expanded to show the higher resolution in the lower altitudes. c) The lowest 120 m expanded.

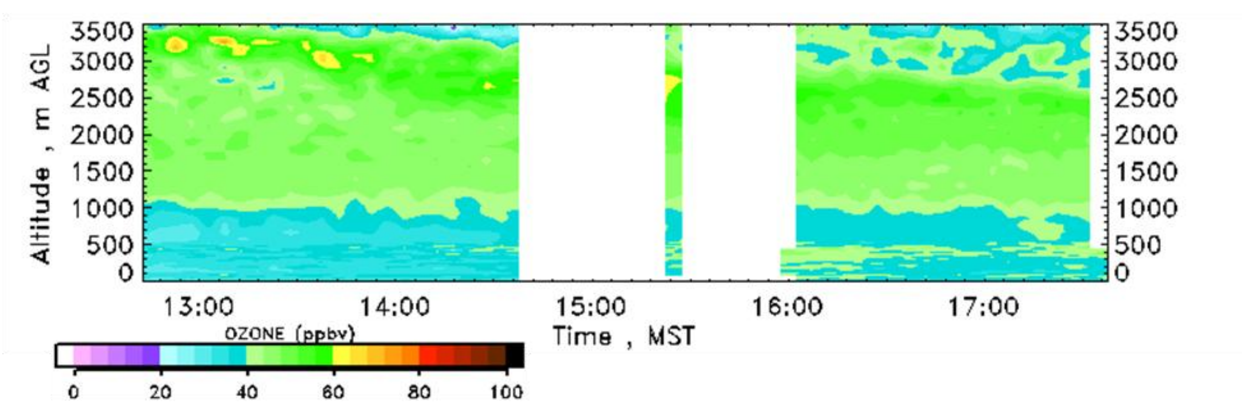

Figure 4. Time-height cross section of ozone concentration from the UBWOS experiment. The individual profiles are composites from three angles as shown in Figure 3, and the concentration is indicated by the colors as shown on the color bar.

modifications to the laser to improve its long-term operating endurance and the addition of mobile truck-based operating capability.

ACKNOWLEDGMENTS

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