Recent Progress in CART Raman Lidar Measurements

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Introduction

The Cloud and Radiation Testbed (CART) Raman Lidar was developed to provide continuous, automated vertical profiling of atmospheric water vapor, aerosols, and clouds. The system was delivered to the Southern Great Plains (SGP) CART site on September 13, 1995, and became operational on September 19, 1995. Routine operation of the system was delayed due to early laser reliability problems, but system reliability has increased dramatically with weekly uptimes in excess of 99 percent now being common. From April 1996 through mid-March 2001, we collected signals from more than 1.7 billion laser shots, accumulating in excess of 16,000 hours (1.8 years) of Raman Lidar data.

General Description

Raman Lidar operates by directing a short pulse of laser radiation into the atmosphere, and temporally and spectrally resolving the backscattered radiation (Goldsmith et al. 1998; Turner and Goldsmith 1999). As in radar, temporal resolution provides information as to where on the laser beam the scattering is being generated. Unlike radar, however, spectral resolution can provide information on what molecules have generated the backscatter signal by detecting signals wavelength-shifted from the laser output by intervals corresponding to their vibrational Raman "fingerprints," in addition to obtaining information on aerosols and clouds by detecting the signal at the laser wavelength. Thus, the water-vapor mixing ratio (grams of water vapor per kilogram of dry air) is directly obtained from the lidar signal by taking a ratio of the backscatter from water vapor to that of nitrogen. Similarly, the aerosol backscatter ratio is obtained from a ratio of the backscatter at the laser wavelength to that of nitrogen. The following products can also be derived from Raman Lidar data (some require ancillary measurements, such as a temperature profile obtained from radiosondes or from Atmospheric Emitted

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Radiance Interferometer [AERI] – Geostationary Operational Environmental Satellite [GOES] retrievals): relative humidity, precipitable water vapor, aerosol backscatter coefficient, aerosol extinction coefficient, extinction/backscatter ratio, and optical thickness (Ferrare et al. 2001; Turner et al. 2001). Currently, data are collected in "bins" of photon counts at 39 m vertical resolution and 1-minute temporal resolution. (The electronics currently being used cannot provide vertical resolution of less than 39 m, but data samples of shorter temporal duration can be obtained, and some measurements have been with 10-second resolution). During data processing, decreased vertical and/or temporal resolution can be traded off for increased sensitivity (signal/noise); the mixing-ratio data product is typically provided at 10-minute resolution with 78-m vertical resolution near the ground with vertical resolution decreased as altitude increases. Useful measurements are typically obtained up to ~4 km during the daytime, and ~12 km during the nighttime.

System Operation History

A variety of system enhancements have been made to improve the uptime of the Raman Lidar since it was first installed. Hardware upgrades include the addition of a wire-mesh hail shield over the enclosure window in April 1997 (before that time, the system could not be left running when the site was unattended), and the addition of a large uninterruptible power supply in February 1999 (so that the system would not be shut down by the very short power glitches that are common at the site). Software upgrades include an improved algorithm for making sure the sky is sufficiently clear before an automatic alignment adjustment is attempted, and implementation of an automated ramp-up in laser energy at system start-up to reduce the likelihood of damage to laser components. Figure 1 displays the improvement in system uptime from April 1996 through our record-breaking month of March 2001 (with a full-month uptime of 99.7 percent, or 742 out of a possible 744 hours). The major cause of extended system downtime, however, continues to be occasional failure of the high-power Nd:YAG laser system. We hope to install a backup laser head so we can quickly switch to this head while the damaged head is being repaired.

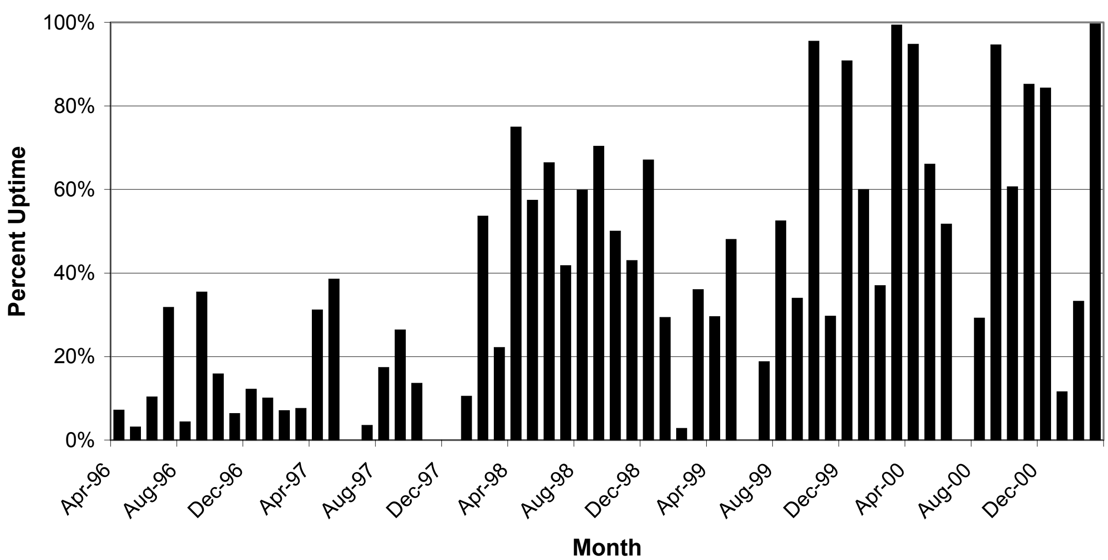

Figure 1. Raman Lidar system uptime by month, April 1996 through March 2001.

Further characterization of the capabilities of the CART Raman Lidar was one of the primary goals of two of the Intensive Operational Periods (IOPs) held during calendar year 2000. During WVIOP2000 (September 18-October 8, 2000), the system obtained measurements for 490.5 out of 504 possible hours (uptime 97.3 percent); during ARM-FIRE Water Vapor Experiment (AFWEX, November 27-December 15, 2000), it obtained measurements for 430.1 out of 456 possible hours (94.3 percent uptime). A variety of intercomparisons are currently underway among the many instruments that took part in these two major campaigns (including a second Raman Lidar, and both ground- and aircraft-based differential absorption lidar systems). The stability of the calibration of the Raman Lidar during these periods is illustrated in Figure 2. In this figure, each point represents a comparison of precipitable water vapor obtained for a 10-minute period by the Raman Lidar to that obtained by the standard CART Microwave Radiometer under clear-sky, nighttime conditions. The Raman Lidar analysis was performed using a single, fixed calibration constant for the 1062 measurements shown in this figure (530 for WVIOP2000 and 532 for AFWEX).

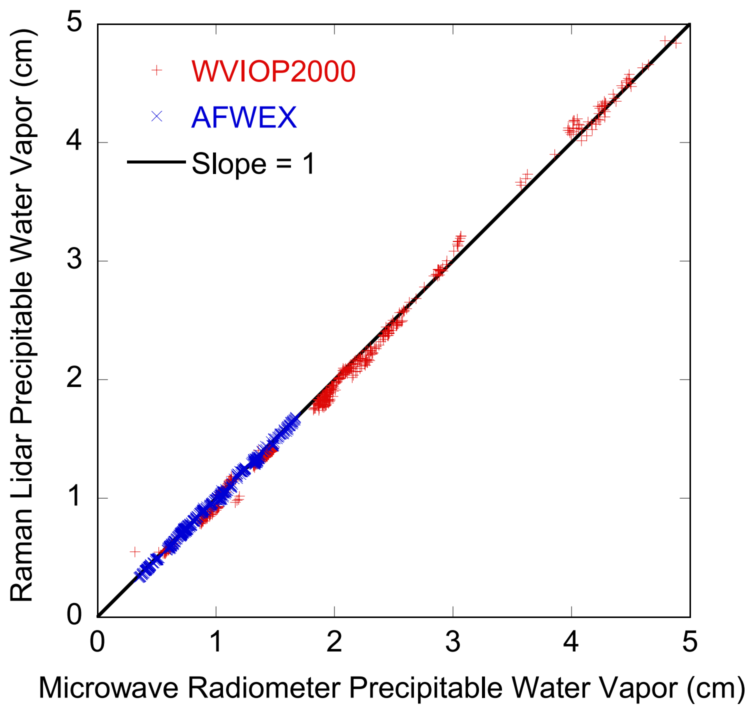

Figure 2. Comparison of clear-sky, nighttime Microwave Radiometer and Raman Lidar measurements of precipitable water vapor during WVIOP2000 and AFWEX.

Conclusion

The quality and quantity of measurements already obtained by the CART Raman Lidar provides an unsurpassed dataset of humidity profiles. Further information on the system and data products, and daily quicklooks from September 1996 through the present, can be found at http://playground.arm.gov/~turner/raman_lidar_quicklooks.html. Additional system upgrades are in progress that will further enhance both the quality of the data, and further improve system reliability. Concurrently, instrument intercomparisons using measurements obtained during WVIOP2000 and AFWEX will provide a more complete understanding of the quantitative capabilities of this instrument.

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