Comparison with Lidar-Derived Water Vapor with Other Moisture Measurements During the CAMEX-2, LASE and WMO Field Campaigns

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Abstract. Three field missions were conducted at Wallops Island, VA in August and September 1995. The NASA Goddard Space Flight Center Scanning Raman Lidar participated in all three campaigns by measuring water vapor for ground truth comparisons. We present water vapor comparisons from 3 lidars, 2 in situ hygrometers, VIZ and Vaisala hygrometers, and an infrared interferometer. The comparisons agree to within 5-10% from the ground up to 7 km.

1 Introduction

Water vapor plays a major role in the Earth's climate and is the most abundant greenhouse gas. Therefore, knowledge of the horizontal and vertical variability of water vapor is required to understand its impact on the climate system. There are many different methods of measuring water vapor, each with its own advantages [1]. Field campaigns allow coincident measurements with different instruments.

Recently, the NASA/Goddard Space Flight Center Scanning Raman Lidar (SRL) participated in three field campaigns held at Wallops Island, VA, USA. The second Convection and Moisture Experiment (CAMEX-2) was conducted during August 1995. The Lidar Atmospheric Sensing Experiment (LASE) Validation Experiment [2] and the World Meteorological Organization (WMO) Balloon Intercomparison were conducted concurrently during September 1995. Water vapor mixing ratio measurements made by the SRL will be compared to other moisture measurements and root-mean-square (rms) and bias differences will be discussed, following a description of the SRL and the field campaigns.

2 System Description

The SRL is a trailer-based system [3] that uses a XeF excimer laser to transmit light at 351 nm. The system operates at 400 Hz with an average output of 12 W in the far-field. A 0.76 m Dall-Kirkham telescope gathers the laser return and the vibrational Raman-shifted returns from O_2 (372 nm), N_2 (383 nm), and H_2O (403 nm) gas molecules. Beamsplitters separate the return beam into low- and high-sensitivity channels for each wavelength to extend the measurement range of the SRL. The data are saved in the form of 1-minute contiguous profiles that possess an altitude resolution of 75 m. Only nighttime taken in the vertical data are used here.

After applying a differential atmospheric transmission correction between the different wavelengths, the ratio of the water vapor and nitrogen signals is proportional to the water vapor mixing ratio (the mass of water vapor to the mass of dry air) in the measured air. The constant of proportionality is determined by comparing with an ensemble of coincident radiosonde profiles of the water vapor mixing ratio.

3 CAMEX-2 and LASE/WMO Campaigns

The SRL was deployed at the Wallops Flight Facility (WFF), Wallops Island, VA (37.94° N, 75.46° W), in support of CAMEX-2 in August 1995, and in support of the LASE validation and the WMO radiosonde comparison field campaigns in September 1995. The SRL was located 3.5 km west of the Atlantic ocean. Typically, aircraft with lidar (ER-2) and in situ hygrometers (Lear and C-130) would fly over the SRL, performing ascending and descending spirals over the site. WFF VIZ and Vaisala radiosondes on balloons were launched approximately 3.2 km east of the SRL. The ground-based Pennsylvania State University (PSU) lidar [4] and the University of Wisconsin (UW) interferometer [5] were located next to the Raman lidar.

4 Moisture Comparisons

In-situ water vapor measurements using a GE 1011 hygrometer were taken from a Lear jet and a C-130 aircraft during LASE. The rms and bias differences of these measurements to SRL one-minute data are shown in figures 1a and 1b. The bias difference generally parallels the rms difference, implying that the random (rms) difference is smaller than the differences shown in figures 1a and 1b.

LASE uses a Ti:Sapphire laser in the 813-819 nm regime, flies on the NASA ER-2. LASE and collects data using a weak and strong line of water vapor, measuring close to the ground with the weak line and down to about 6 km with the strong line [6]. Rms and bias differences between ten-minute SRL and LASE weak line data are shown in figure 1c. This comparison of four profiles shows the SRL measurements to be slightly wetter than the LASE weak line data.

The VIZ radiosonde uses a carbon hygristor moisture element to measure relative humidity, while the Vaisala radiosonde uses a thin-film capacitive element

sensor [3]. These packages were frequently launched on the same balloon, and yet yielded different measurements within the lowest 2 km. The rms and bias

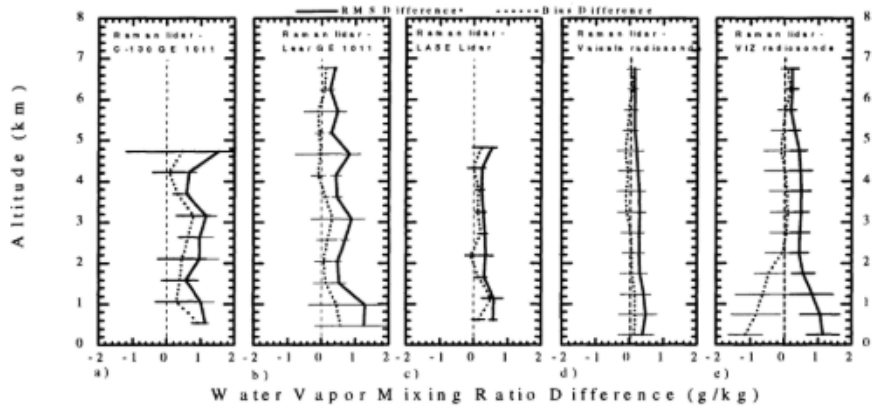

Fig. 1. Rms and bias differences between the SRL and: a) C-130 GE 1011 hygrometer, b) Lear GE 1011 hygrometer, c) LASE, d) Vaisala, and e) VIZ water vapor data. Rms is solid line and bias is dotted line.

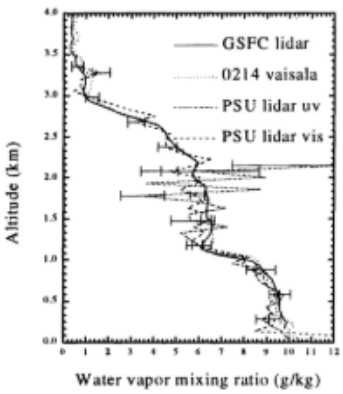

Fig. 2. Profiles of the SRL, the Vaisala, and both the PSU (uv and visible) water vapor ratios for Sept. 20, 1995 0214 UT.

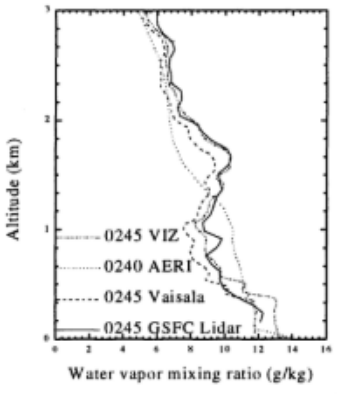

Fig. 3. Profiles of the SRL, Vaisala, VIZ, and AERI water vapor mixing ratios mixing for Sept. 13, 1995 0245 UT.

differences between ten-minute SRL-Vaisala and ten-minute SRL-VIZ measurements from all 3 campaigns are shown in figures 1d and 1e. The SRL-Vaisala rms difference was < 0.5 g/kg at all altitudes. Below 2 km, the VIZ measurements disagreed with the SRL by as much 1 g/kg.

The PSU lidar is a multi-wavelength Rayleigh/Raman lidar developed as part of the Laser Atmospheric Measurement Program (LAMP). The LAMP lidar uses a doubled (532 nm) and quadrupled (266 nm) Nd:YAG laser expanded through a 5X telescope at a rep rate of 20 Hz. Water vapor is measured in the ultraviolet and visible wavelengths [4]. Profiles of ten-minute SRL and 30-minute PSU data from September 20, 1995 UT are shown in figure 2.

The UW AERI, an infrared radiometer, observes the spectrum of downwelling radiances in the 3.3-18 micron range. AERI obtains a three minute measurement in a zenith field about every 10 minutes [5]. Ten-minute water vapor mixing ratio profiles of SRL data and AERI data from September 13, 1995 are shown in figure 3, along with VIZ and Vaisala data.

Summary

We have shown comparisons of measurements from three lidars, two radiosondes, two aircraft in-situ hygrometers, and an infrared radiometer. The SRL, LASE, water vapor hygrometers, and VIZ and Vaisala radiosondes measurements agree to within 5-10% over an altitude range of 0-7 km.

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