P1.3 HOWARD UNIVERSITY RAMAN LIDAR RESULTS DURING WAVES 2006 FIELD CAMPAIGN

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1. INTRODUCTION

The WAVES (Water Vapor Variability – Satellite/Sondes) 2006 field campaign took place at the Howard University Research Campus in Beltsville, MD from July 7 to August 10. The field campaign was intended to provide quality measurements of water vapor and ozone for comparison with AURA satellite retrievals and to quantify the air quality (see Whiteman et al. 2006 b). The operations include intensive observations by multiple radiosonde / ozonesonde sensors and several lidar systems during overpasses of the AURA satellite. Lidar measurements are acquired by four lidar systems: NASA/GSFC Scanning Raman Lidar (SRL), NASA/GSFC Aerosol/Temperature Lidar (ATL), a Micropulse Lidar from Penn Sate and Howard University Raman Lidar (HRL). Coordinated lidar measurements took place as well at University of Maryland, Baltimore County (backscatter and Raman lidars) in order to provide information about the spatial variability of the aerosol and water vapor. In addition to the lidar / radiosondes operations, continuous measurements are taken by a 31m instrumented tower (for temperature, flux, wind etc), various broad-band and spectral radiometers, microwave radiometer, Doppler C-band radar, chemical and aerosol parameters as well as wind profiler operated by the Maryland Department of Environment (MDE) as well as a sun photometer, and a Suominet GPS system.

The HRL system operates at the third harmonic (typical operating power is 10 W) of an Nd:YAG laser and acquires data within three channels, at 354.7 nm (elastic backscatter and pure rotational Raman respectively), 386.7 nm and 407.5 nm (Raman scattering from nitrogen molecules and water vapor molecules). Eye-safety is accomplished by means of a 15X beam expander. The laser beam and telescope divergences are 50 µrad and 250 µrad respectively. The data acquisition is achieved with Licel Transient Recorders which allow both photon counting and analog acquisition. The combination of both methods [1](“glue-ing”) gives maximum dynamic range. For
the data processing, the following corrections are applied: response time correction, dark-current and background subtraction, and noise reduction (data smoothing using a moving average: constant over time and variable in space). The first data of the HRL system were acquired in 2004 and the WAVES experiment is the first major participation within a field campaign aimed at intra-lidar comparison.

The present results show the temporal and spatial retrievals of the water vapor mixing ratio (WVMR). Preliminary results show excellent agreement between HRL and SRL systems throughout the useful range of water vapor and aerosol profiles on one hand and between HRL and radiosondes (RS92) profiles. Examples of RS92 comparisons will be shown in the present paper. SRL comparisons will be shown during conference presentation, where special attention will be given to the day time/night time measurements performances, including error analyses.

2. LIDAR GLUING PROCEDURE

Combination of analog (AD) and photon counting (PC) signals allows us to use the analog data in the strong signal regions and the PC data in the weak signal regions. The idea is to form ordered pairs of (AD, PC) data in a region where both are considered to be performing in a reasonably linear fashion and perform a regression. Prior to the regression, the photon counting data are corrected for pulse pileup using a non-paralyzable assumption. The regression determines the gain coefficient that is then used to convert the AD scale to a "virtual" photon countrate scale (see Whiteman et al. 2006a). First, the gluing coefficients are determined profile by profile by regression (at least 25 points are used in regression) after background subtraction (red, green and blue

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curves in Fig. 1 represent the gluing coefficients for aerosol, nitrogen and water vapor respectively). In the second step, the mean gluing coefficients (for each of aerosol, nitrogen and water vapor) are determined (see the lines in Fig. 1). Few criteria are involved in determining the mean gluing coefficients. First, only profiles with a regression correlation coefficient R^2 larger than 0.99 (aerosol), 0.99 (nitrogen) and 0.97 (water vapor) are selected. A mean and STD are calculated for R^2. Profiles outside the boundaries defined by mean ± STD for R^2 are eliminated. For the remaining profiles, the mean and STD are computed for the gluing coefficients. Further, profiles lying outside the boundaries defined by the mean ± STD for gluing coefficients are excluded. The remaining set of profiles determines the final mean gluing coefficients. The criteria involved assure us to exclude outliers when determining the mean gluing coefficients (e.g. spike in water vapor around profile 20 in Fig. 1).

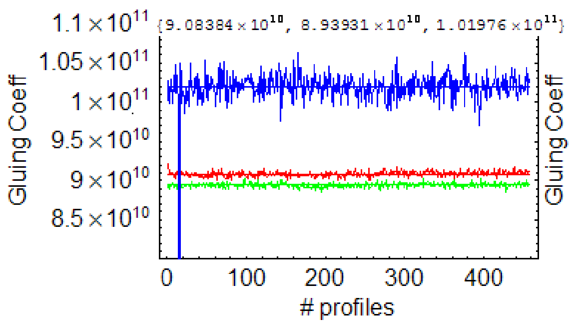

Fig. 1. Gluing coefficients for August 12, 00:05 - 07:42 UT. The red, green and blue curves represent the gluing coefficients for aerosol, nitrogen and water vapor respectively. The coefficients are in units of V Hz^{-1}.

3. INCOMPLETE OVERLAP CORRECTION

In the WVMR expression there is the ratio of the water vapor overlap function to the nitrogen overlap function. In order to extract useful information from the region of the incomplete overlap region, a correction has to be applied. In the present study, a correction function was determined from the ratio of the WVMR from radiosondes (RS92) and lidar profiles. Eight sets of profiles were chosen over the entire experiment period. The individual ratios as well as their mean are shown in Fig. 2 (a). An analytical function was defined to match the experimental mean [Fig. 2(b)]. The fit for the mean ratio is determined as a polynomial function of degree 9 as a function of exp(-h), where h is the height (altitude).

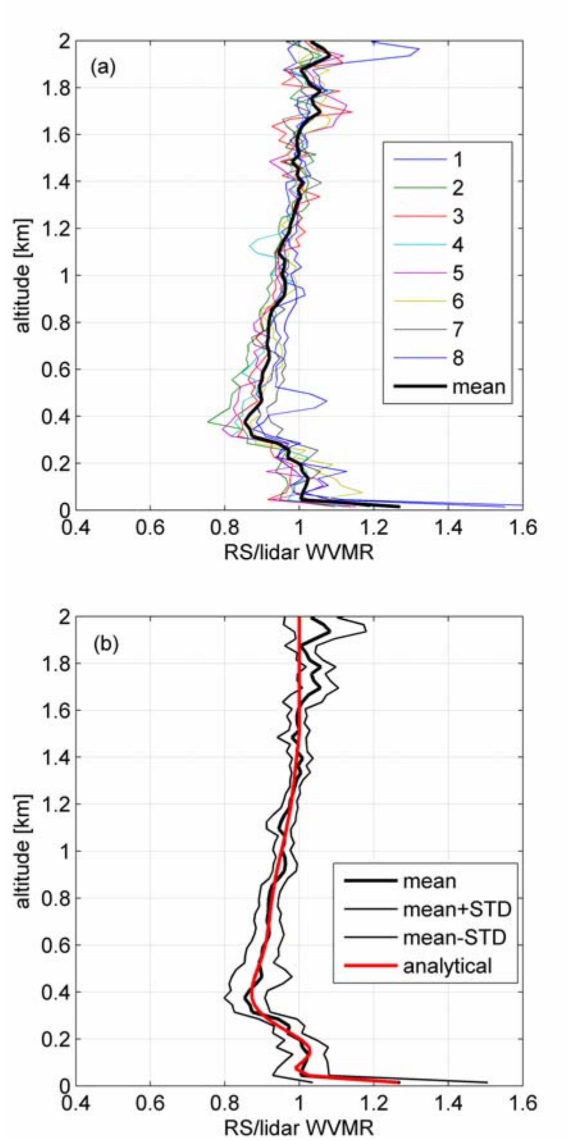

Fig. 2. (a) Individual and mean ratios of RS92 to lidar WVMR. (b) Mean and STD and the analytical fitting.

4. LIDAR WATER VAPOR MIXING RATIO CALIBRATION

First, the differential transmission term is computed using radiosondes pressure and temperature measurements to account for the molecular attenuation and a constant aerosol extinction coefficient derived from the Aeronet aerosol optical depth and the length of the boundary layer height to account for aerosol attenuation.

The lidar calibration for WVMR is performed by comparison of the lidar integrated precipitable water (IPW) with the microwave radiometer (MWR) IPW data for night time periods. The lidar profile for WVMR is corrected for the region of incomplete overlap. Due to the increased noise with the range for the lidar signals, the IPW above altitudes of 8 km is calculated from radiosondes WVMR data, accounting for approximately 1 - 2 % of the total IPW as measured by MWR. Fig. 3 (a) shows the MWR IPW and the initial lidar IPW. The MWR to lidar IPW ratio gives the lidar calibration constant for WVMR. The individual calibration points are shown by black boxes. Initially, the mean and the STD are computed. The outliers outside the boundaries defined by STD = ± 5 % of the mean are excluded. With the remaining set of points, the mean and STD are computed [red and green lines in Fig. 3 (b)]. For this particular set of data (August 12) the mean calibration is 117 while its STD is 1.6.

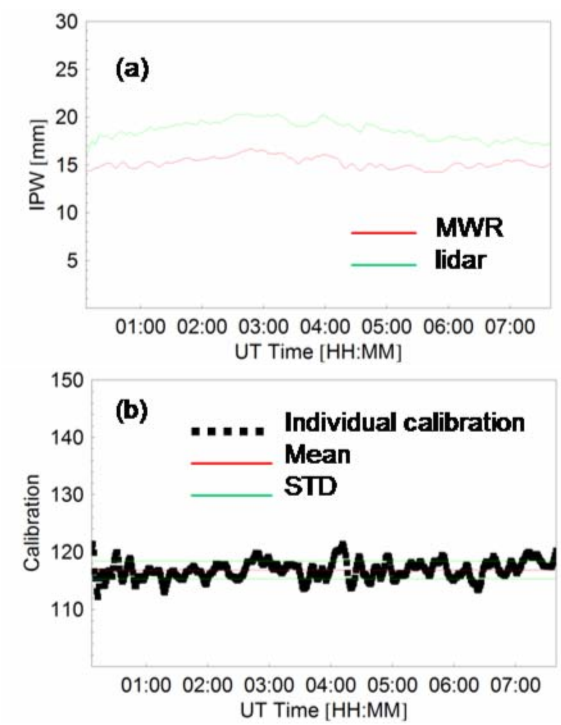

Fig. 3. (a) IPW as given by MWR (red curve) and by lidar (green curve). (b) The calibration constant given by the IPW ratio of MWR to lidar. Mean and STD are 117 and 1.6 respectively.

5. RADIOSONDES COMPARISONS

The radiosondes comparisons within this study were performed with respect to NASA GSFC RS92 radiosondes. Below we show comparisons for night time periods. The lidar average profiles are averages over five minutes (5 profiles) and 31 minutes (31 profiles). A moving average was performed on the altitude scale as well. For 5 min averaged lidar profiles we expect a better agreement with RS92 in the boundary layer (BL) region while for 31 min averaged lidar profiles we expect a better agreement with RS92 above BL.

The first example is a comparison from July 11 (RS92 launch time: 6:05 UT). The met tower WVMR at 1.5 m and 31.8 m are 14 and 15.7 g kg^{-1} respectively. Fig. 4 (a) shows the two lidar profiles and the RS92 profile. Note that x-axis for Fig. 4 (a) is in logarithmic units (where the units must be read as $10^{-0.5}$, 10^{0} etc). Fig. 4 (b) shows the relative differences between RS92 and 5 min lidar profile. A good agreement is met for the first ~ 2.5 km, where the relative differences are smaller than 10 %.

A second example is from July 20 (RS92 launch time: 5:54 UT). Fig. 5 shows the lidar and RS92 profiles (a) and their relative difference (b). A good agreement is met for the first 3 km. The met tower WVMR at 1.5 m and 31.8 m are 18.7 and 17.7 g kg^{-1}.

The final example is from August 12 (RS92 launch time: 6:01 UT). The met tower WVMR at 1.5 m and 31.8 m are 10.3 and 9 g kg^{-1}. In this example we observe a bias between RS92 profile and lidar profiles. Accordingly the difference errors increase.

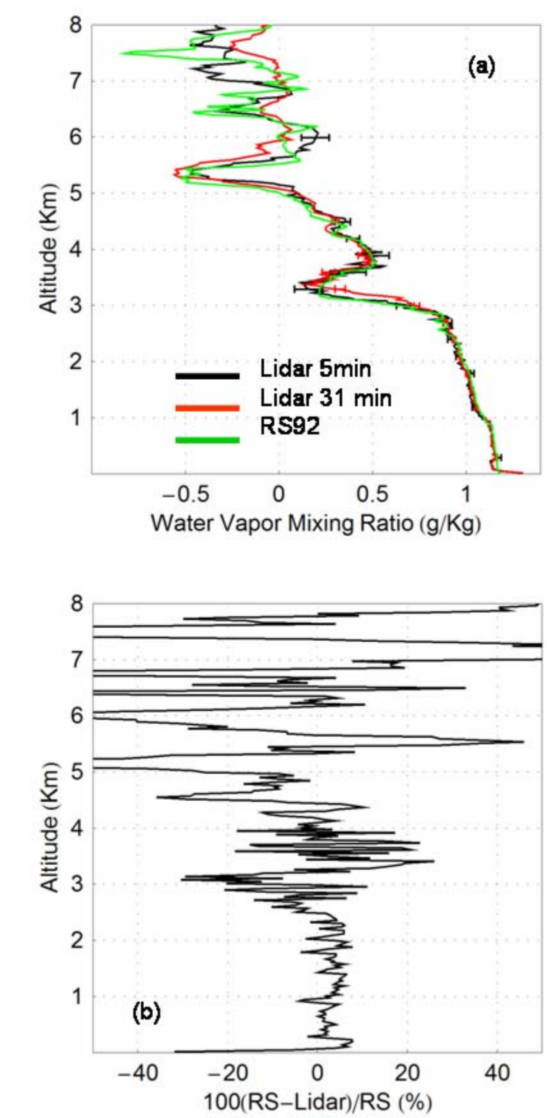

Fig. 4. (a) RS92 (green curve) and averaged lidar WVMR profiles (black curve – 5 min, red curve – 31 min); the met tower WVMR at 1.5 m and 31.8 m are 14 and 15.7 g kg^{-1}. (b) the relative error between RS92 and the mean lidar profiles.

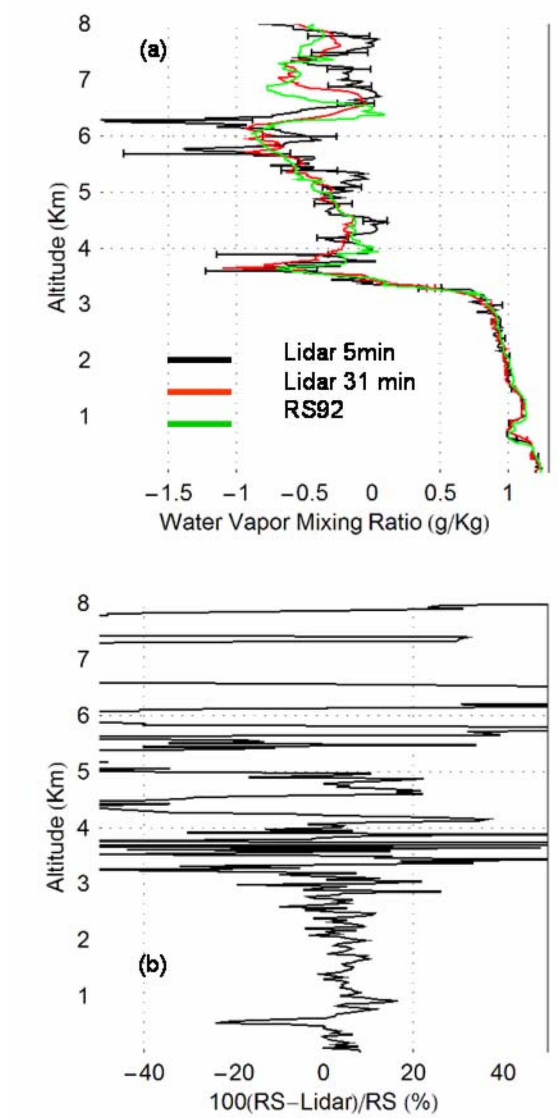

Fig. 5. (a) RS92 (green curve) and averaged lidar WVMR profiles (black curve – 5 min, red curve – 31 min); the met tower WVMR at 1.5 m and 31.8 m are 18.7 and 17.7 g kg^{-1}. (b) the relative error between RS92 and the mean lidar profiles.

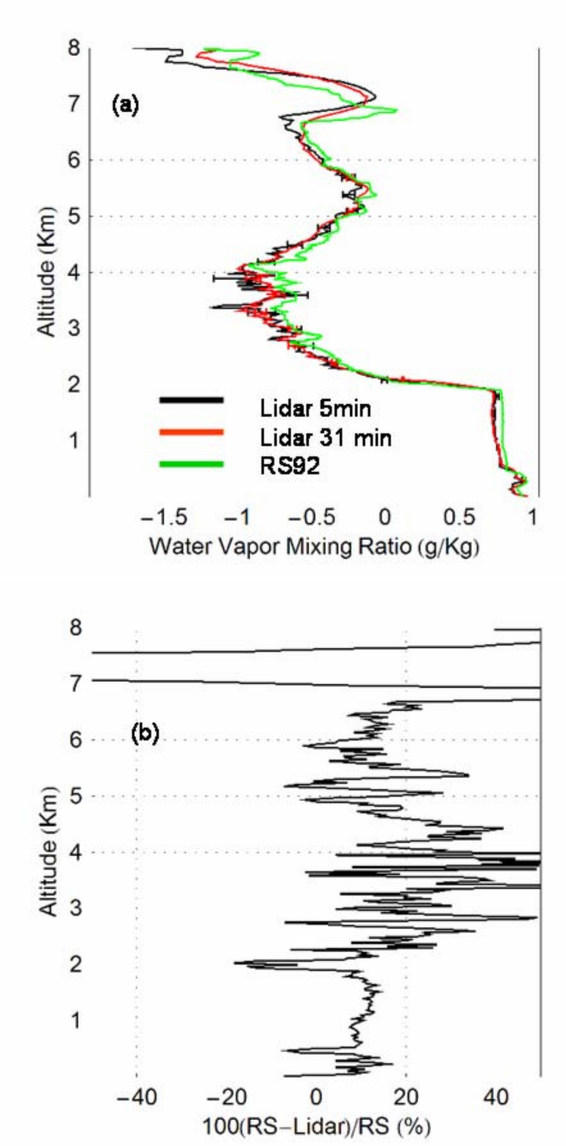

Fig. 6. (a) RS92 (green curve) and averaged lidar WVMR profiles (black curve – 5 min, red curve – 31 min); the met tower WVMR at 1.5 m and 31.8 m are 10.3 and 9 g kg^{-1}. (b) the relative error between RS92 and the mean lidar profiles.

6. CONCLUSIONS

The first RS92-lidar comparisons for WVMT show promising results. Acceptable comparisons usually are met on the BL region where the WVMR values are large. As we go up, above the BL region, the WVMR decrease substantially. Consequently, the relative difference between two small quantities will result in large percentages.

In the near future, we will focus within the potential sources of errors. At this time we are aware of the following sources of errors which are propagated within the calculation procedure: RS92 WVMR precision (different corrections are underway and comparisons with CFH radiosondes are performed), correction function for the incomplete overlap region (it is directly influenced by the precision of the RS profile); calibration constant (directly influenced by the accuracy of the incomplete overlap correction function as well as by the smoothing/averaging techniques).

Comparisons with SRL profiles will be shown during the conference (P1.3 poster).

7. REFERENCES

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