WATER VAPOR LIDAR SYSTEM AND MEASUREMENTS AT THE JPL TABLE MOUNTAIN FACILITY

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ABSTRACT

A new Raman lidar at the Table Mountain Facility (TMF) of the Jet Propulsion Laboratory (JPL) in California (34.4°N, 117.7°W) has being measuring water vapor in the free troposphere for almost a year now. The lidar was designed to reach accuracies better than 5% anywhere up to 12 km altitude, and with the capability to measure water vapor mixing ratios as low as 1 to 10 ppm near the tropopause and in the lower stratosphere. The current system is not yet fully optimized but has already shown promising results as water vapor profiles have been retrieved up to 18 km altitude. Following a brief description of this system, steps taken towards validating the lidar will be described. These include the comparison of results from a nearly 1-year dataset of simultaneous and co-located lidar and radiosonde profiles. Also, a brief, 2-week intercomparison campaign with water vapor lidars from the Goddard Space Flight Center (GSFC) will be presented.

1. INTRODUCTION

The impetus for the development of this new system was for validation of water vapor profiles being obtained by several instruments onboard the AURA satellite and for long-term measurements according to the goals of the Network for the Detection of Atmospheric Composition Change (NDACC, formerly know as the Network for the Detection of Stratospheric Change – NDSC). With these objectives, lidar measurements are being made several times per week and, especially during this initial stage of development, Vaisala RS-92K PTU (pressure, temperature, humidity) radiosondes are being launched simultaneously.

2. RAMAN LIDAR

Due to the very low mixing ratio of water vapor near the tropopause and in the lower stratosphere, Raman lidar measurements in this region are noise limited. To try and maximize the signal-to-noise ratio we use very high laser pulse energies (up to 900 mJ/pulse at 355 nm), a large aperture telescope (91 cm diameter), with narrow field-of-view (≤600 µrad), and narrow spectral bandwidth filters for the water vapor Raman channels (0.6 nm). In addition to the large telescope, three 75 mm diameter telescopes are used to collect returns from low altitudes.

In all, the lidar receiver comprises eight channels, as shown in fig.1. There are three channels each for the water vapor and nitrogen Raman returns at 407 nm and 387 nm respectively, and two for the elastic returns at 355 nm. The 355 nm returns are primarily used for the derivation of temperature profiles and will not be considered further in this report. The Raman signals from the large telescope are divided with a ~1% beamsplitter (B4). In addition to extending the dynamic range of the photon counting system, this enables better corrections for pulse pile-up saturation effects. The corresponding signal from the small telescope is designed to have similar magnitude as the 1% signal from the large telescope. This then allows for the correction of overlap effects at low altitudes in signals from the large telescope.

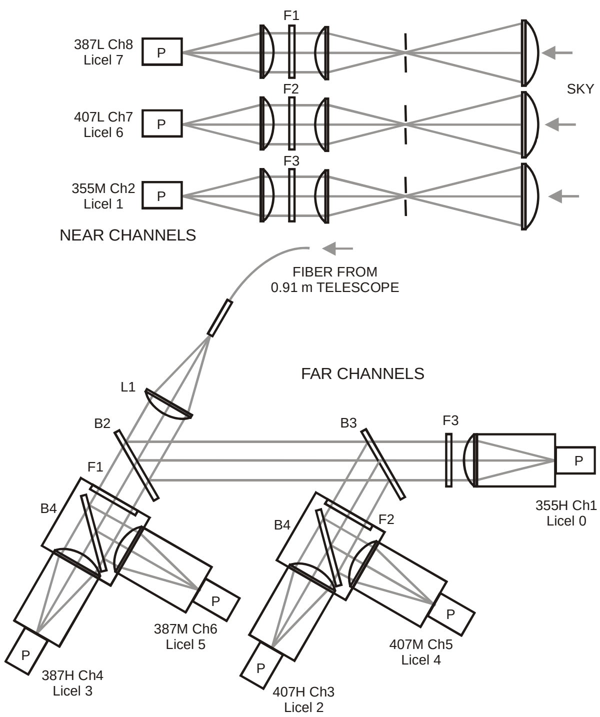

Fig.1. Water vapor lidar receiver.

The signals are input to a Licel photon-counting multichannel scaler (MCS) which has a fundamental resolution of 7.5 m. However, 10 bins are typically summed together so the maximum resolution in the profile is 150 m (2 x Nyquist).

3. RESULTS

Water vapor profiles are only obtained at night and the highest altitudes are reached at the times of no moon. For a routine measurement, signals are integrated for a two hour period. However, to obtain measurements near the tropopause, full night integrations have occasionally been made.

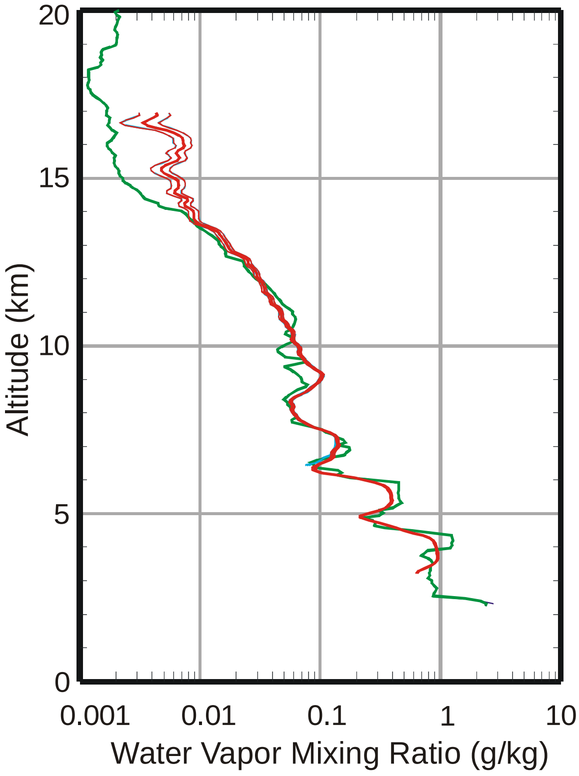

Fig.2. Lidar water vapor profile from June 16, 2005 (red curve with error limits) compared with simultaneous radiosonde (green curve).

An example of a 2-hour lidar measurement is shown in fig.2. The profile from a Vaisala RS92K PTU sonde, launched at the beginning of the lidar integration, is shown for comparison. It should be noted that the altitude of TMF is 2.3 km. The sonde profile begins at ground level and the lidar profile approximately 1 km above the ground. Agreement between the two measurement techniques is excellent down to water vapor mixing ratios just below 10 ppm or about 14 km altitude in this case. There are known problems with sondes in these very dry regions but differences between the measurements cannot be attributed with any confidence to either one of the instruments alone.

4. INTERCOMPARISON CAMPAIGN

A preliminary campaign was organized in June 2005 to inter-compare water vapor profiles obtained by the JPL lidar and PTU sondes, and the GSFC AT and STROZ-Lite mobile lidar systems. The campaign took place at TMF from 7 to 21 June, during which time the JPL lidar obtained data on 11 nights, with multiple profiles measured on 8 of these nights; the AT lidar acquired data on 13 nights and the STROZ-Lite lidar on 15 nights; PTU sondes were launched on 9 nights with 2 or more sondes being launched on 5 of these. Observations were synchronized in time to the greatest extent possible.

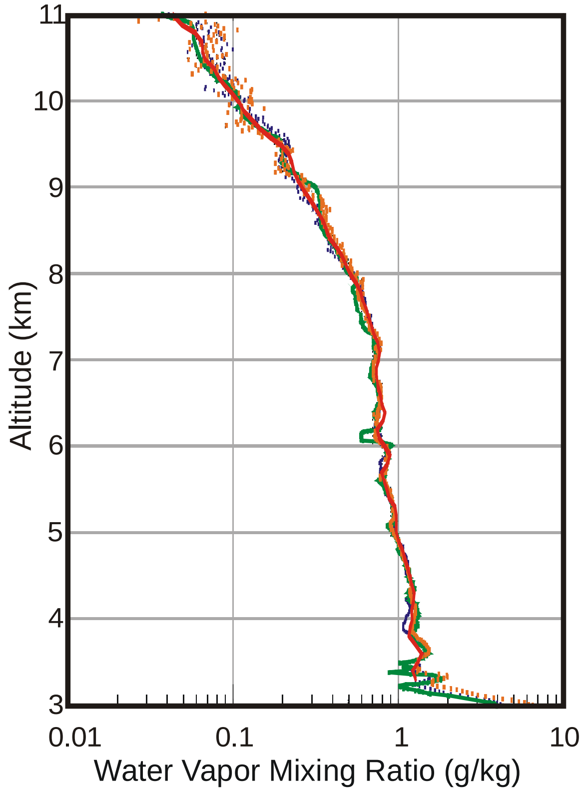

Fig. 3. Profiles from June 13, 2006. Red-JPL, Blue-AT, Orange-STROZ, Green-Sonde

Fig. 3 shows the profiles obtained on one night during the campaign. Due to the excellent agreement, it is difficult to see the four different profiles as they are so well overlapped. The upper altitude is approximately 11 km representing the limit of the GSFC lidars.

A large scale intercomparison campaign is being planned for September 2006 that will bring together all of the instruments described here, an additional mobile lidar, frost-point type sondes capable of measurements at low mixing ratios, and microwave radiometer(s). This will finally determine the performance of the JPL Raman lidar near the tropopause and lowers stratosphere.

Acknowledgements

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