Raman Lidar Claims Independence

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Introduction

- Raman water vapor Lidar is considered a tier 2 instrument in GRUAN
- A weakness is that most Lidar measurements are calibrated with respect to another water vapor measurement and are therefore not independent.
  - The transfer of calibration from another instrument to the Raman Lidar is one of the largest sources of systematic uncertainty in the Lidar measurement.
- It is also advisable to perform the calibration frequently in an effort to randomize this source of systematic uncertainty. *(Whiteman et al. 2012)*
- The Lamp mapping technique offers a means to both independently and frequently calibrate Raman Lidar water vapor measurements
  - Agreement with radiosonde based calibration to better than 5% *(Venable et al., 2011)*

Objective

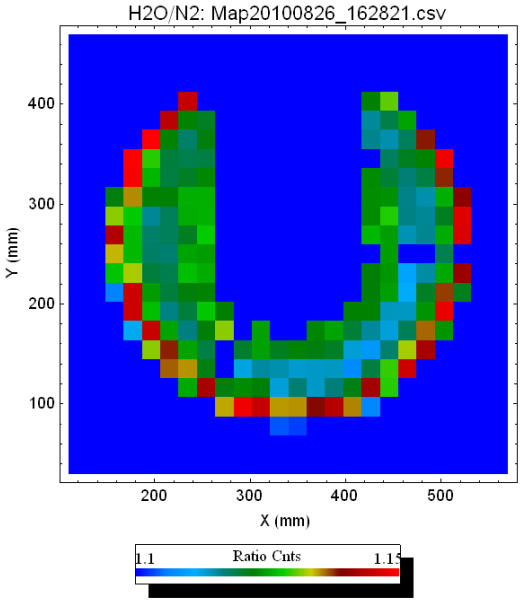
- Transfer the independent calibration capability to a mobile system *(ALVICE NASA GSFC)*
- To independently calibrate Raman Lidar water vapor and develop techniques for performing frequent calibration

Motivation

- Improve the quality of Raman Lidar based water vapor time series for trend detection
- To perform independent calibration efforts in the field

Lamp Mapping Technique

- A halogen lamp is scanned over the aperture of a telescope while normal data acquisition is occurring.
- This provides information, point-by-point, on the optical efficiency of the complete optical system.
  - the optical efficiency can change significantly across the optical train
- 15 minutes required to perform a standard mapping



ALVICE & HURL Systems

Common Capabilities of the ALVICE and HURL Systems

Both use narrow band-pass filters and a narrow field-of-view telescope and are capable of measuring:

1. Rayleigh/Mie at ~354.7 nm
2. Raman scattered photons from nitrogen molecules at ~386.7 nm, and
3. Raman scattered photons from water vapor molecules at ~407.5 nm

Tour on Thursday

HURL

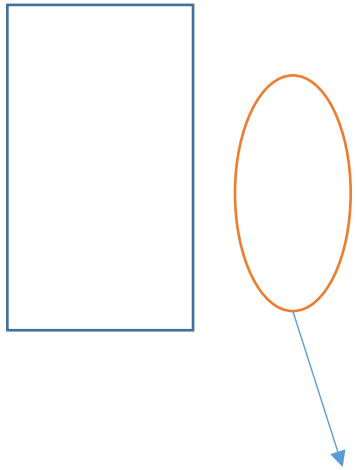
400 mm Primary ~16 in
Fiber Coupled
Interest is in Troposphere
~10 W laser power

ALVICE

600 mm Primary ~24 in
Direct Coupled
Additional Channels
Pure Rotational Raman (Temperature)
Interest includes UT/LS
~18 W laser power

Water Vapor Calibration Equations

- Temperature dependent terms can have a >5% effect depending on system design
- Water vapor cross sections are calculated from *ab initio* work of Avila et al., 2004

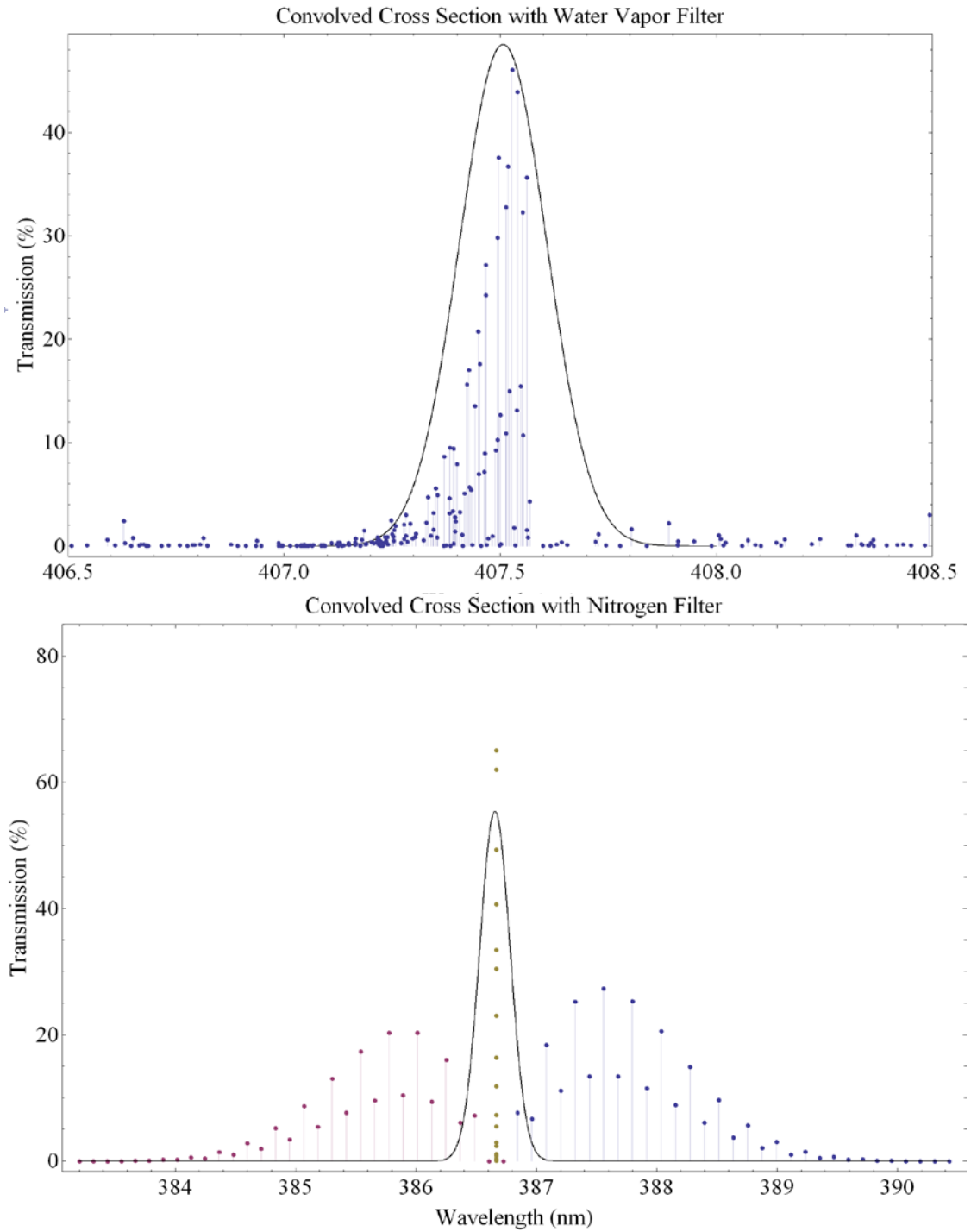


$$C_R = 0.485 \frac{\kappa\,(\lambda_N)}{\kappa\,(\lambda_{wv})} \frac{\frac{d\sigma_N}{d\Omega}}{\frac{d\sigma_{wv}}{d\Omega}} \frac{\varepsilon(\lambda_N)}{\varepsilon(\lambda_{wv})}$$

$$\frac{\kappa(\lambda_N)}{\kappa(\lambda_{wv})} = \frac{S_{out}(\lambda_N)}{S_{out}(\lambda_{wv})} \frac{S_{in}(\lambda_{wv})}{S_{in}(\lambda_N)}$$

Filter Efficiency $\frac{\varepsilon(\lambda_N)}{\varepsilon(\lambda_{wv})}$

- Filter transmission curves are needed to determine calibration constant.
- Convolution of theoretical cross sections and filter functions give the F(T) terms and are a crucial component of the calibration



LMT Calibration Results

- Transfer of LMT calibration technique to ALVICE tested during the ALVICE NDACC deployment to U. Western Ontario 2012
- Preliminary radiosonde and independent calibrations are within 1 sigma of each other but results were based on earlier filter transmission curves
- Currently working on procedures to improve filter measurement consistency

HURL C_R Comparison		
	Radiosonde	LMT
C_R	195.8 ± 8.7 g/kg	186.8 ± 13.7 g/kg
Number of Runs	19	10

Agreement with traditional Radiosonde technique to better than 5% (Venable et al., 2011)

Preliminary ALVICE C_R Comparison		
	Radiosonde	LMT
C_R	104 ± 5 g/kg	96.5 ± 5 g/kg
Number of Runs	16	16

Summary and Conclusions

- Lack of independent calibration for Raman water vapor lidar is a large source of systematic uncertainty in the measurements
  - Frequent calibrations are desired to randomize this source of systematic uncertainty
- Venable et al. 2011 published work indicates an agreement of the LMT derived Raman water vapor lidar calibration and that of radiosonde within 5%
- An independent, lamp-based calibration has been developed for the mobile NASA/ALVICE system.
  - the initial results indicate agreement within 7% for the calibrations determined independently and based on radiosonde comparisons
- Improved techniques for characterizing interference filters are being developed
- *Tour on Thursday*