We thank the reviewer for his (her) time, consideration and useful comments.

Comment

The authors could put the technical information in more tables to ensure more easy information to the readers.

Reply

The essential technical data is summarized in table 1 and more details are given in the text but following the comment we considered it useful to extend the table content. The modified table is:

Transmitter		Receiver	
Nd:YAG laser- third harmonic:		*Four fiber coupled parabolic mirrors:*	
Wavelength:	354.7 nm	Focal length:	1 m
Spectral line width:	0.7 cm^{-1}	Diameter:	0.3 m
Rep. rate:	30 Hz	Axial displacement: (to expander axis)	235 mm
Pulse energy:	300 mJ	FOV:	3x0.20 and 1x 0.22 mrad
Pulse duration:	8 ns		
Beam expander- Galilean type		*Polychromator- Diffraction grating based*	
Expansion ratio	15x	Bandwidth (FWHM): (H_2O and N_2)	0.33 nm
Transmitted beam:		Central wavelength	H_2O 407.45 nm
Divergence:			
calculated	0.06 mrad		N_2 386.7 nm
measured	0.09±0.02 mrad	Efficiency:	33 % (peak at H_2O)
Diameter:	140 mm	*Photodetectors (Hamamatsu)*	
		H_2O	R7600U-200
		N_2 and O_2	H6780

Comment

Page 6870, Line 12: difficult => difficulties

Reply

The text is grammatically correct because difficult relates to errors but probably makes the sentence difficult to understand. Therefore it will be replaced by:

"In addition, radiosonde measurements suffer from systematic errors that are difficult to correct and from essential sonde-to-sonde variations between instruments from different producers and operational principles and even between instruments of the same batch."

Comment

Page 6870, Line 19: new => delete this word: H2O Lidar is not new, also not in the sense of operational. (for the periode at ARM-site 1998.03.01 - 2012.06.12 http://www.arm.gov/data/vaps/rlprof/10rlprofmr1turn; Reichardt, J. ; Wandinger, U. ;Klein, V. ; Mattis, T.; Hilber, B. ; Engelbert, D. ; Begbie, R. ; Berger, F. H.: RAMSES, das Wasserdampf-Ramanlidar des Deutschen Wetterdienstes. In: Promet 37 (2011), Nr. 3, S. 119-128)

Reply

We do not state that the water vapor Raman lidar is a new instrument, but that it is a new instrument for the national meteorological services. The following lines of the introduction clarify this statement (page 6871, line 22 to line 6 on page 6872):

"Raman lidars have been used for high-resolution vertical profiling of water vapor within the troposphere since the early 70-ies of the last century. Most of the measurements were performed for research purposes and at night time (Whiteman, 1992; Ansmann 1992, Vaughan, 1998; Balin, 2004). First daytime measurements were possible using laser wavelength shorter than 300 nm because at these wavelengths the solar light is absorbed by stratospheric ozone (Renault 1980, Cooney 1985). The vertical range of such lidars is however, limited to about 2 km, mainly due to tropospheric ozone absorption. The use of a narrow field-of-view (NFOV), narrow band (NB) receiver allows operation at visible and near UV wavelengths with distance range extended up to the mid troposphere (Goldsmith, 1998).

The successful long-term operation of the first automated NFOV, NB lidar – CART (Goldsmith, 1998) motivated the German (Engelbart, 2006), the Swiss (Simeonov, 2010) and the Dutch (Apituley, 2006) meteorological services to establish programs aiming at the development of continuously operational water vapor lidars."

The ARM lidar- CART is mentioned explicitly in the text.

To avoid ambiguities however the sentence on Page 6870, lines 19 -20 of the original manuscript:

"Therefore, new operational instruments for near-real time observations of the tropospheric water vapor field are needed."

will be modified to:

“Therefore, national meteorological services need a new type of autonomous, continuously operated (24h, 365/7) instruments for near-real time, high spatial resolution observations of the tropospheric water vapor field.”

The quoted material *“Reichardt, J. ; Wandinger, U. ;Klein, V. ; Mattis, T.; Hilber, B. ; Engelbert, D. ; Begbie, R. ; Berger, F. H.: RAMSES , das Wasserdampf-Ramanlidar des Deutschen Wetterdienstes. In: Promet 37 (2011), Nr. 3, S. 119-128)”* is in German and not from a peer reviewed journal or conference. Furthermore we were not able to find the article in Promet and would be grateful if the reviewer could supply the exact link to the publication. In the paper we quote the information available to us at the submission date about RAMSES. The references list will be updated with the following article:
Reichardt J., Wandinger U., Klein V., Mattis I., Hilber B., and Begbie R. : RAMSES: German Meteorological Service autonomous Raman lidar for water vapor, temperature, aerosol, and cloud measurements, Appl. Opt. 51, 8111-8131, 2012
which was published after the submission of our material

Comment

Page 6871, line 5: "expensive", "sophisticated", and "complicated" => this can be stated by everybody and tells nothing. Please, name what you compare, cite and give some numbers.

Reply

The meaning of expensive, sophisticated and complicated is explained further in the text (Page 6171, lines 16 to 21):

“Contrary to a DIAL, a Raman lidar does not require tunable laser source with specific and highly stabilized wavelengths. Furthermore, the Raman data-treatment algorithm is significantly simpler than the DIAL algorithm, and allows data retrieval from the incomplete overlap region. Because of all these advantages and because of the higher reliability, Raman lidars are preferred for operational use in meteorology from ground-based stations (Goldsmith, 1998; Engelbart, 2006; Simeonov, 2010; Apituley, 2006).”

To clarify the text on line 5 page 6871 the sentence will be modified to:

“The need for an expensive and sophisticated tunable laser source and the complicated data treatment is another obstacle for implementing DIAL as an operational, ground based instrument for operational meteorology.”
The three quotations supporting “expensive and sophisticated” (Wulfmeyer, 1998b; Bruneau, 1991; Browell, 1998) and one about the complexity of the data treatment will be added (Bösenberg, 1998) to the references.

Comment

Page 6871, Line 15, after cross sections => and instrument functions (for instance the filter curve for taking into account the temperature dependence of the rotational-Raman lines and their suppression)

Reply

In this sentence the need for instrumental calibration for a Raman lidar in contrast to a DIAL is accentuated. The two principal calibration techniques are just mentioned without further details. The temperature dependence of the calibration constant is discussed in more details in chapter 2-Theory of operation (from line 18 on page 6875 to line 2 on page 6876) and in chapter 3.2.3-Spectral unit (from line 21, page 6883 to line 11, page 6884). There we show that the temperature correction can be avoided by selecting the central wavelength and the bandwidth of recorded water vapor spectrum.

Comment

Page 6877, Line 6 and 7: This is the motivation for using gratings? Did you think about possible additional effects by using gratings?
Gratings may cause that the passed light is not equally distributed around the optical axis? This effect may also be wavelength dependent?

Reply

The quoted sentence on lines 6 and 7 reflects the main motivation. More details are given in chapter 3.2.- Spectral unit (page 6883 lines 11 to 19) as shown below:

"To achieve long-term data consistency, system stability and negligible range dependence of the calibration constant, the Raman signals are spectrally isolated by a fiber coupled grating polychromator. The use of a grating-based, instead of a filter-based, polychromator eliminates the long-term gradual shift of the central wavelength and any changes in the transmission related to the interference filter based devices. Furthermore, grating polychromators, contrary to interference-filter based polychromators, allow easy selection of the central wavelength position and bandwidth, hence optimization of the efficiency and minimization of the systematic errors related to the temperature dependence of the Raman cross sections."

The second part of the comment is not clear. The diffraction gratings perform spatial separation of the different wavelengths of the incident light accordingly to the grating equation $m\lambda = d(\sin\alpha + sin\beta)$ where m is the diffraction order, λ the wavelength, d the groove spacing, α and β are the incident and diffracted light angles respectively. Therefore strictly speaking we cannot use the term optical axis for the diffracted (passed in the comment) radiation.
Grating polychromators (as other optical systems) suffer from optical aberrations such as coma, astigmatism, field curvature etc. These aberrations were taken into account during the design of the polychromator. Grating magnification (not an aberration) was also taken into account as well (lines 24-28 on page 2884).

Comment

Page 6884, Line 3: The number 1% is clearly to low (compare for instance Whiteman, D. N.: Examination of the traditional Raman lidar technique. I. Evaluating the temperature-dependent lidar equations, Appl. Opt., 42, 2571-2592, 2003; page 2574, Fig. 2). So the calculation values in Fig. 8 are questionable and should be shown in *more steps.*

Reply

There are several reasons for the apparent at first glance difference in the value of the temperature dependence of the integral of the product of the Raman cross section and the instrument transmission.

First, the position of the central wavelength of the water vapor channel in the quoted paper (author D. Whiteman) is different from the one in our lidar. The central wavelength for the results shown in Fig. 2 of the quoted paper is 407.53 nm (3654 cm^{-1}) nm compared to 407.45 nm (3649 cm^{-1}) for our system. As seen from Fig.4 of the Whiteman paper, the values of the integral for a central wavelength 407.45 nm is practically constant for bandwidths bigger than 20 cm^{-1}. In the same paper (Page 2577, line 12 from the bottom) the author states: "If this passband is determined primarily by an interference filter, then tilting the filter by~1° assuming a filter's effective index of refraction of~1.5 to center it at 3649 cm^{-1} (407.43 nm) would essentially eliminate the temperature sensitivity.", which is in perfect agreement with our results.

Second, the relative difference of the integral in the Whiteman paper is calculated for the temperature range 200-300 K relative to its value at 300 K. The temperature range in our paper is -60° + 40 C° (213-313 K) and the difference is calculated relative to 0° C.

Comment

Page 6891: The equation (10) is not retraceable. Please, explain in detail using also N_measured = N_x + N_Bx and sigma=sqrt(N).

Reply

There is a typographic error in the equation (missing square in the denominator parts of the square root). The correct equation is:

$$\frac{\partial q(z)}{q(z)} = \sqrt{\frac{\sigma_{H2O}^2(z) + \sigma_{BH2O}^2}{[N_{H2O}(z) - N_{BH2O}]^2} + \frac{\sigma_{N2}^2(z) + \sigma_{BN2}^2}{[N_{N2}(z) - N_{BN2}]^2}}$$

Otherwise the equation is derived following the standard error propagation techniques. It can be seen in similar form in almost all papers concerning water vapor Raman lidars e.g. Whiteman D. Appl Opt 2003 v. 42 No 15 p. 2596. Therefore we do not give detailed description on the derivation.

Taking into account the comment and to clarify the subject the text describing equation 10 will be modified as follows:

"Following common error propagation techniques the relative error $\frac{\partial q(z)}{q(z)}$ of the water vapor measurement is estimated from the standard errors of the Raman signals $\sigma_x(z)$ and their respective daytime background $\sigma_{Bx}(z)$ can be presented as:"

The dependence of the standard deviation on signal count-number is presented as text (lines 21-23 on page 6890) as follows:

“The statistics of the signals detected in photon-counting mode is governed by the Poisson distribution i.e. the standard error is equal to the square root of the number of photons counted.”
but not as an equation.

Comment

Page 6891, line 22 - 24: The radiosonde measurements are also not free of errors. The main errors are listed for instance in Herold et al. doi:http://dx.doi.org/10.1175/2011WAF2222448.1). So, it should also be noticed which (errors of the radiosonde measurement have been regarded.

We fully agree, the radisondes, even those using reference methods like “ chilled mirror”, suffer from systematic errors but at present this is the most practical way to calibrate the lidar. Because of the importance of the problem number of papers are dedicated to comparison between radiosondes and Raman lidars and to the radiosondes systematic errors. Main sonde drawbacks are outlined briefly in the introduction referring to the latest WMO report. However since this paper is dedicated mostly to lidar design and to avoid excessive paper length, the calibration and validation of the instrument is described in more details in the companion paper.