Atmospheric
Measurement
Techniques
Discussions

Open Access

Interactive comment on "Tropospheric water vapour and relative humidity profiles from lidar and microwave radiometry" *by* F. Navas-Guzmán et al.

F. Navas-Guzmán et al.

fguzman@ugr.es

C4526

Answers to the referees (AMT-2013-254)

28 February 2014

Referee 1

The paper presents the retrieval of water-vapor related profiles using a lidar with capabilities of measurement of Raman-shifted radiation by water vapor and nitrogen. Two kinds of profiles are considered, namely water-vapor mixing ratio profiles and relative humidity profiles, the latter obtained using the synergy between the lidar providing water-vapor mixing ratio profiles and a microwave radiometer delivering temperature profiles.

Concerning water-vapor mixing ratio profiles, contributions are found in an improved calibration method of the lidar against reference radiosonde data and in a statistical analysis of measurements carried out over one year of the water-vapor mixing ratio as a function of height ranges.

The retrieval of relative humidity profiles through the lidar / microwave radiometer synergy is perhaps the paper's most original contribution. In this respect, the authors should clarify if this method has been previously reported and, if not, stress

its originality. A statistical analysis of relative humidity as a function of height ranges,parallel to that of water-vapor mixing ratio, is also presented.

As the referee suggests we have commented in several sentences in the paper the originility of this method.
In the abstract (lines 9 to 13):
"Moreover, a new approach to obtain relative humidity profiles by combination of simultaneous profiles of temperature (retrieved from a microwave radiometer) and water vapour mixing ratio (from a Raman lidar) is addressed."
In subsection 3.3 (lines 364 to 366):
"In this section a new approach to retrieve relative humidity profiles from the combination of Raman lidar and microwave radiometer measurements is discussed".

The paper is well organized, but the labeling of the sections is a little misleading. For example, under the title of "Methodology" (section 3), one would expect not only the basics of the water-vapor mixing ratio measurement using water vapor and nitrogen Raman channels of a lidar, but also the calibration issues and the lidar / microwave radiometer synergies. It is thus suggested that sections 4 and 5 are converted into subsections of a more general "Methodology" section.

Following the referee's suggestion we have restructured the section 3. The section has been also renamed (**"Water vapour and Relative Humidity retrievals"**). The new subsections are now:

3.1 Water vapour profile from Raman lidar measurements.
3.2 Raman lidar water vapour calibration.
3.3 Retrieval of relative humidity using Raman lidar and temperature from microwave radiometer.

Moreover, we have modified the last paragraph in the introduction where we have up-

dated the new structure of the paper. The text read now as follow (lines from 69 to 75):

"The paper is organized as follows: in section 2, the instrumentation and the experimental site are briefly described. Section 3 deals with the methodology applied to retrieve water vapour and relative humidity profiles, including details about the lidar calibration. A statistical analysis of water vapour and relative humidity is presented in section 4. Finally conclusions are found in section 5".

Present section 3 deals with a known method, already described in at least J. E. M. Goldsmith et al., "Turn-Key Raman Lidar for Profiling Atmospheric Water Vapor, Clouds, and Aerosols", App. Opt., 37, 21, pp. 4979-4990 (1998), and in references Mattis (2002) - which should be Mattis et al. (2002) - and Guerrero-Rascado et al. (2008) - which it closely follows, not surprisingly given common co-authors - of the present paper, and could probably be shortened by referring to these papers. Note in addition that there is a typo in Eqs. (3), (4) and (5), where the factor $exp\{-\int_0^R [\alpha(r,\lambda_{N_2}) + \alpha(r,\lambda_{H_2O})]\, dr\}$ should be $exp\{\int_0^R [\alpha(r,\lambda_{N_2}) - \alpha(r,\lambda_{H_2O})]\, dr\}$.

We have summarized a little bit this part, and the equation 3 have been deleted. Following the referee's suggestions we have added some references. Moreover, the typo in the equations has been corrected. The text in the paper and the equations after these changes read as (lines 189 to 205):

"The water vapour mixing ratio is defined as the ratio of the mass of water vapour to the mass of dry air in a sample of the atmosphere (Goldsmith et al., 1998). We can obtain the ratio $N_{H_2O}(R)/N_{N_2}(R)$ that is proportional to the water vapour mixing ratio (w) from equations 1 (Guerrero-Rascado et al., 2008). Assuming identical overlap factors and range-independent Raman backscatter cross sections for the two signals this ratio can be expressed as:"

$$\frac{N_{H_2O}(R)}{N_{N_2}(R)} = \frac{P(R,\lambda_{H_2O})}{P(R,\lambda_{N_2})} \frac{K_{N_2}\sigma_{N_2}}{K_{H_2O}\sigma_{H_2O}}$$

$$\exp\{ \int_0^R [\alpha(r, \lambda_{H_2O}) - \alpha(r, \lambda_{N_2})]\, dr \}$$

and thus

$$w(R) = \frac{P(R, \lambda_{H_2O})}{P(R, \lambda_{N_2})} K \exp\{ \int_0^R [\alpha(r, \lambda_{H_2O}) - \alpha(r, \lambda_{N_2})]\, dr \}$$

Because the basics of the method are well known, the first sentence of the abstract ("we outline a method to obtain water vapour mixing ratio profiles from a Raman lidar") should probably be made more targeted, pointing out the particularities of the calibration method proposed.

Following the referee's suggestion we have slightly modified the abstract in order to emphasize the particularities of the calibration method and also the innovation of the approach to retrieve relative humidity profiles. The abstract now read as:

"In this paper, we outline an iterative method to calibrate the water vapour mixing ratio profiles retrieved from Raman lidar measurements. Simultaneous and co-located radiosonde data are used for this purpose and the calibration results obtained during a radiosonde campaign in Summer and Autumn 2011 are presented. The water vapour profiles measured during nighttime by the Raman lidar and radiosondes are compared and the differences between the methodologies are discussed. Moreover, a new approach to obtain relative humidity profiles by combination of simultaneous profiles of temperature (retrieved from a microwave radiometer) and water vapour mixing ratio (from a Raman lidar) is addressed. In the last part of this work, a statistical analysis of water vapour mixing ratio and relative humidity profiles obtained during one year of simultaneous measurements is presented."

The statistical analyses presented seem to apply to night-time data only, because of Raman lidar limitations to operate in day time. This should be clearly stated, and it is suggested that a discussion on the usefulness of the results is included in

C4530

view of this restriction to night-time measurements.

We already mentioned in several parts of the manuscript that the water vapour from Raman lidar were restricted to night-time measurements. Anyway following the referee's comment we have also clarified this point in the abstract and in the conclusions of the work:

Abstract (lines 6 to 9):

"The water vapour profiles measured during nighttime by the Raman lidar and radiosondes are compared and the differences between the methodologies are discussed."

Conclusions (lines 555 to 557):

"This study presents the water vapour measurements performed with Raman lidar and radiosondes during nighttime at Granada station."

C4531