CAELI WATER VAPOUR RAMAN LIDAR CALIBRATION AT THE CABAUW EXPERIMENTAL SITE FOR ATMOSPHERIC RESEARCH

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ABSTRACT

Water vapour is a crucial parameter in atmospheric physics. Concentrations are low at upper tropospheric altitudes, but radiation effects are sensitive to water vapour abundance at these levels. Obtaining reliable data of low water vapour concentrations in the upper troposphere is challenging. The Raman lidar technique for water vapour can meet this challenge, however, the Raman lidar water vapour data rely on an external source for calibration. For the Raman lidar Caeli in Cabauw, operational radiosondes launched in De Bilt, about 22 km North-East of the lidar location are routinely used for this. Differences in space and time between the observations influence the consistency and quality of the calibration.

Various in-situ and remote observations of humidity are available at Cabauw that are better collocated and synchronised with the lidar measurements. These collocated observations could also be used for the lidar calibration as an alternative to the radio soundings. Among the possibilities are GNSS and microwave radiometer and tower based in-situ humidity measurements. In this paper we explore the possibilities for applying those for the Raman lidar calibration in Cabauw.

1. INTRODUCTION

As atmospheric temperatures increase due to the continued anthropogenic injection of carbon dioxide, it is expected that water vapour concentrations will increase as well, inducing an enhancement of the greenhouse effect. All climate models predict this enhancement, but diversity in sensitivity to changes in radiative perturbations is present amongst the models [6]. Upper tropospheric water vapour, i.e. water vapour between the levels of 250 – 400 hPa plays a special role in our climate. Even though the amount of water vapour at those levels is small, the sensitivity of the outgoing radiation to water vapour is dominated by upper-tropospheric water vapour [13]. Consequently, it is of great importance to accurately record the upper tropospheric water vapour.

The low concentrations of water vapour in the upper troposphere and lower stratosphere (UTLS) make measurement at these altitudes very difficult. The sensitivity of operational radiosonde sensors suffers under conditions of very low ambient temperatures and relative humidities, limiting the range of high quality measurements to the low and middle troposphere [8]. Research-grade balloon-borne frost-point hygrometers remain the best source of high quality water vapour measurements in the UTLS [15] but are too expensive to be used on an operational basis. Also, satellite measurement uncertainties remain high near the tropopause due to the abrupt change of mixing ratio at the tropopause level [10]. Due to the capabilities of Raman lidar for monitoring water vapour at low concentrations [7] it is being adopted in networks such as NDACC [9] and the GCOS Reference Upper Air Network (GRUAN) [5].

The Raman lidar observations of water vapour solely rely on the measurement of Raman lidar returns of both water vapour and of nitrogen (N_2). The ratio of the two lidar signals can be shown to be proportional to the water vapour to dry air mixing ratio and, in principle, only need a single point within the profile for calibration. Radiosondes are often used for this by extracting a matching range interval from the lidar and the sonde to obtain the required calibration constant. However, the launch site of the sonde may not be the same as the lidar location, and the sonde drift during ascent [12] raises the issue of representativity with respect to the lidar, especially in cases of high atmospheric variability .

At the Cabauw Experimental Site for Atmospheric Research (CESAR) in the Netherlands (51°58'N, 4°56'E), a suite of in situ and ground based remote sensing instruments are routinely operated to provide synergy in atmospheric observations. In particular, in-situ and remote observations of aerosols, clouds, radiation and precipitation related measurements are made [11]. These observations are made for both monitoring of climate change, as well as process studies. CESAR is one of the initial GRUAN sites.

Various in-situ and remote observations of humidity are available at Cabauw that are well collocated and synchronised with the lidar measurements. These observations could also be used for the lidar calibration as an alternative to the radio soundings, avoiding issues with representativity. Among the possibilities are GNSS and microwave radiometer (providing integrated column values of water vapour) and tower based in-situ humidity measurements. In this paper we explore the possibilities for applying those for the Raman lidar calibration in Cabauw.

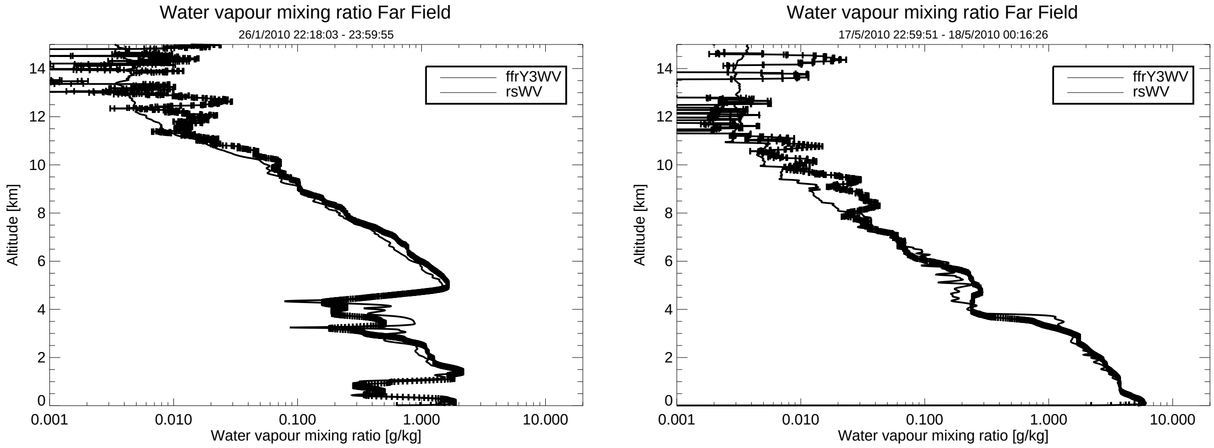
2. INSTRUMENTATION

2.1. Caeli

Caeli is the CESAR water vapour, aerosol and cloud lidar and is set up as a multiwavelength Raman lidar [1]. It is deployed in Cabauw, as a key instrument for CESAR to strengthen the sites capabilities as a profiling station for atmospheric research and climate studies. The instrument

(a)

(b)



(c)

(d)

(e)

(f)

Figure 2: Overview of sample results. The atmospheric conditions are shown in the time-height plots of the range corrected lidar data (RCS) for the periods during the night of 26-27 Jan. 2010 with thin cirrus (2a) and during the night of 17-18 May 2010 with a volcanic dust layer between 4 and 6 km (2b). Lidar and sonde humidity profiles after lidar to sonde calibration are shown in the panels (2c) and (2d). In (2e) and (2f) the comparison of in-situ and lidar humidity data is shown. In the bottom part of the figure the in-situ values at the 200 m level of T_{air} and T_d are plotted from which Q_{tower} is derived. The top part of the figure shows Q_{tower} with a continuous line and Q_{lidar} indicated by markers.

355, 387 and 407 nm starting at about 500 m. However, due to the optical design of the instrument, near-identical optical paths exist in the receiver for the signals related to the same emitted wavelength; in this case 355 nm. This was experimentally verified using the EARLINET QA procedures. Since Q_{lidar} is obtained from a ratio of the 407 and 387 nm signals, overlap functions of both signals are expected to cancel, to some extent, due to the near-identical optical paths of the signals in the receiver. Our results show that virtually no overlap effects seem to remain at this level. Moreover, the examples also show that the results can be obtained consistently over time. More cases were analysed than shown here, giving similar results. A full analysis of the data is ongoing.

5. CONCLUSIONS

Raman lidar specific humidity data obtained with sonde calibration compare favourably with in-situ humidity measurements from the tall tower in Cabauw. Geometrical effects in the lidar receiver almost completely cancel out consistently due to the design and implementation of Caeli. Although a full analysis of all available data is not yet complete, is seems that long term consistency checks of the lidar humidity calibration using the in situ tower data that are well collocated and synchronised with the lidar are useful.

This paper presents work in progress. At the time of the conference, more results are expected and better founded conclusions can be drawn.

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