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Caeli Water Vapor Raman Lidar Calibration Using the 213 m Tower In-Situ Measurements at the Cabauw Experimental Site for Atmospheric Research

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Abstract: In this work, we use the tower-based in-situ humidity measurements for the calibration of the Raman water vapor lidar deployed at the Cabauw Experimental Site for Atmospheric Research (Caeli), evaluating its stability throughout the year. Calibrated water vapor profiles from the lidar were compared with operational radiosonde data with no significant difference. Also, a direct comparison between the lidar and tower humidity measurements in high time resolution at 200 m is shown. The day-to-day variability of the calibration constant was found to be smaller than 2%, for both day and nighttime operations.

1. Introduction

Few instruments can measure atmospheric water vapor mixing ratio profiles as precisely and accurately as Raman lidars can. It can be shown that the ratio of the Raman backscatter from water vapor and nitrogen molecules is proportional to the specific humidity, and accurate retrievals can be performed as long as an accurate proportionality (calibration) constant is used. Traditionally, better calibration accuracy is achieved by means of an external reference for the water vapor, being the measurements from operational radiosondes most commonly used for that [1]. However, differences in space and time between observations can substantially affect calibration consistency and quality.

For Caeli, the multi-wavelength Raman lidar deployed at the Cabauw Experimental Site for Atmospheric Research (CESAR) [2,3], in the Netherlands, a better alternative for the balloon-based calibration is available, as the meteorological sensors along the 213 m tower on the site offers a unique, continuous, and better collocated reference for the specific humidity [4].

In this work, we present the results for the tower-based calibration, as well as a comparison of the lidar retrievals with radiosonde profiles and high time resolution tower measurements of water vapor at 200 m.

2. Results and Conclusions

For the calibration, about 1 hour of cloud-screened lidar measurements are accumulated and directly compared with simultaneous and collocated in-situ water vapor mixing ratio measurements from the tower at the 200 m level. Although this altitude is below Caeli's full overlap height (around 600m), the near identical optical paths for the N2 and H2O Raman signals allows for the cancelation of the overlap function between these two channels,

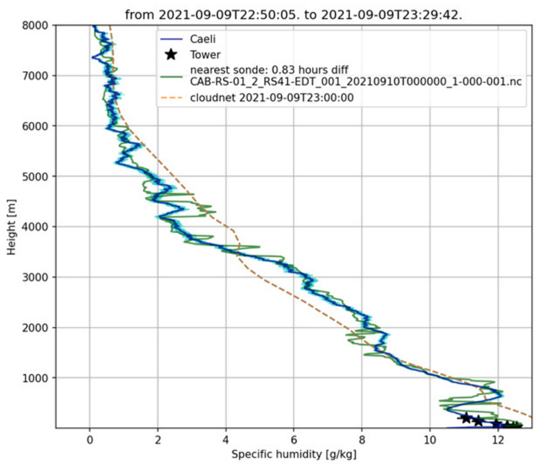

Figure 1: Water vapor profiles from Caeli (tower-based calibration), nearby radiosonde (green), Cloudnet (ecmwf – dashed line), and in-situ tower (back stars).

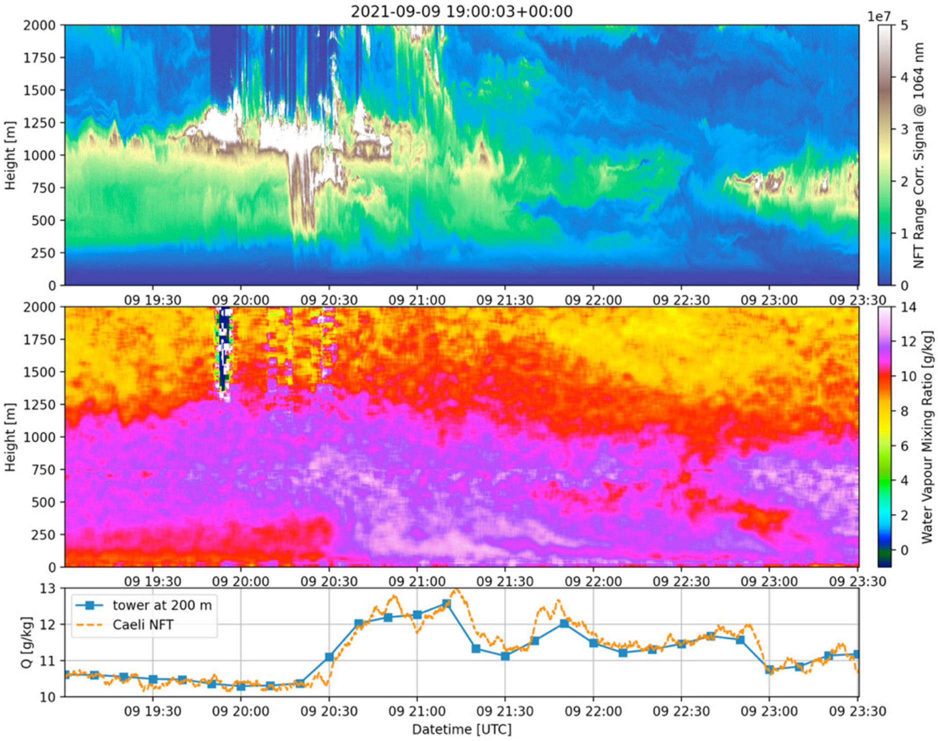

Figure 2: Caeli's Range corrected signal (top), water vapor mixing ratio (middle) and specific humidity comparison at 200 m with tower data.

with virtually no remaining effect observed at the 200 m level.

By comparing the tower-calibrated lidar humidity profile with data from a nearby sonde (figure 1), no significant difference was found. However, is important to note that the differences in launch time, sites and drift during ascent can impact the representativity of this comparison, and more cases are needed for a better validation.

Figure 2 shows the humidity field measured by Caeli with a time and height resolution (moving average) of 5 min and 52.5 m, respectively, along with the direct comparison with the tower measurements at 200 m, which shows a remarkable agreement and stability over the observational period.

From 37 tower-based calibrations in 2021, including both day and nighttime measurements, the day-to-day (sample) standard deviation of the calibration constant was smaller than 2%, which shows a remarkable stability of the calibration constant. Also, no statistically significant trend (due to aging, for instance) has been observed.

This is an on-going work. The tower-based calibration constant is being calculated for all days where lidar and tower data are available (starting from 2008). Since there are not many restrictions for the atmospheric conditions under which the tower-based calibration is possible, we expect that the number of cases will increase tremendously, allowing for a more details statistics and comparison with other calibration methods. Also, the high accuracy of the tower-based calibration can be used to evaluate other indirect methods for tracking changes in the calibration constants from Raman lidars (for instance, via solar background or photometer measurements).

3. References

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