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Calibration of the Raman Lidar at the Barbados Cloud Observatory

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The Max Planck Institute for Meteorology has been conducting atmospheric measurements on the Caribbean island of Barbados with Raman lidars starting in 2010. We present our methods for calibrating temperature and water vapor retrievals from these measurements. Raman lidars measure water vapor by the number density ratio of water vapor to nitrogen molecules, from the amount of vibrational Raman scattered light by both H_2O and N_2. As there are instrumental uncertainties in the lidar backscatter signal, this data must be calibrated using reference measurements such as radiosondes or ground-based weather stations. We use a combined approach including local balloon soundings, regular soundings at the Barbados airport (11 km distant), and multiple weather stations at the Barbados Cloud Observatory (BCO). The most stable calibration method fits the Lidar profiles to a combination of ground stations, with an adjustment for the typical boundary layer water vapor gradient. Since the weather stations show systematic differences in measured H_2O at the same location, their values have to be adjusted to match a trusted source. For this, we consider the small set of BCO balloon soundings as most reliable since they include a pre-launch calibration procedure. This method yields calibrations with low variance and continuous data availability.

The Raman lidar can also measure temperatures by Rotational Raman scatter of air molecules. We define the Pure Rotational Raman Scatter (PRRS) ratio as the intensity ratio of PRRS lines with opposite temperature sensitivity. The PRRS ratio links to the air temperature with two dependent calibration constants, which are derived by comparing to balloon soundings. Further, we use the dependence of the two constants to solve for a single independent calibration constant, which we show to be sufficiently stable in time to model the calibration for time periods where no soundings are available. The calibrated temperature can be used to calculate relative humidity, with errors within 10% common for up to 6-8 km altitude. The Lidar also gives backscatter coefficients by calibrating to expected aerosol scatter in clear-sky volumes, and extinction coefficients as the range derivative of molecular backscatter coefficients. Finally, we measure depolarization ratios which allow distinguishing water droplets from ice crystals.