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Differential absorption lidar for water vapor isotopologues in the 1.98 µm spectral region: sensitivity analysis with respect to regional atmospheric variability

Jonas Hamperl[1], Myriam Raybaut[1], Jean-Baptiste Dherbecourt[1], Patrick Chazette[2], Julien Totems[2], and Cyrille Flamant[3]

[1]DPHY, ONERA, Université Paris Saclay, Palaiseau, France
[2]Laboratoire des Sciences du Climat et de l'Environnement (LSCE), UMR 1572, CEA-CNRS-UVSQ, Gif-sur-Yvette, France
[3]Laboratoire Atmosphères Milieux et Observations Spatiales (LATMOS), UMR 8190, CNRS-SU-UVSQ, Paris, France

Improved understanding of the variability underlying the distribution of stable water isotopologues in the troposphere, using both observations and modelling, has proven to be invaluable to study processes related to the hydrological cycle on a local as well as global scale. To date though, existing observation means (CRDS from ground-based or airborne platforms, passive remote sensing from space) only provide a partial picture of the complexity of the process at play due to their limited spatial or temporal coverage. On the other hand, laser active remote sensing, and in particular differential absorption lidars (DIAL) can deliver reliable, continuous, highly resolved (150 m, 10 min) profiles of $H_2{}^{16}O$ and $HD^{16}O$ in the lower troposphere, thereby providing observational insights into small scale processes such as evapotranspiration above continental surfaces and mixing in the planetary boundary layer.

Such a lidar system is currently in development (WaVIL project funded by ANR) that will operate at 1.98 µm where water isotopologues exhibit close but distinct absorption features, sensitive photodetectors are commercially available, and where pulsed laser emission over 10 mJ can be achieved using for instance parametric conversion.

In order to assess the expected instrument performances and to evaluate the potential of a ground-based system for simultaneous measurement of $H_2{}^{16}O$ and $HD^{16}O$, we performed an error budget based on an end-to-end simulator. Lidar backscatter signals were simulated for different instrument-specific and atmospheric parameters. On the instrument side, calculations were performed for a commercial InGaAs PIN photodiode and for a state of the art low-noise HgCdTe avalanche photodiode. The sensitivity to environmental factors was investigated exemplarily for mid-latitude, arctic, and tropical environments where both vertical water vapor and aerosol variability were accounted for. Vertical profiles of aerosol extinction and backscatter coefficients were derived from the AERONET database (https://aeronet.gsfc.nasa.gov/) and extrapolated to the 2 µm spectral region, taking statistical seasonality into account. Performance simulations have been also conducted using vertical profiles derived from a field campaign where water vapor isotopologue concentrations and aerosol extinction were measured. We will outline the majority

biases for such a lidar system and how statistical errors can be mitigated in a view of a forthcoming airborne DIAL instrument.