Methodology for Water Monitoring in the Upper Troposphere with Raman Lidar at the Haute-Provence Observatory

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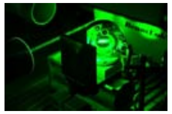


Abstract

A Raman water vapour lidar has been developed at Observatory of Haute-Provence to study the distribution of water in the upper troposphere and its long term evolution. Some investigations have been proposed and described to ensure a pertinent monitoring of water vapour in the upper troposphere. A new method to take into account the geophysical variability for time integration processes has been developed based on the stationary of water vapour. Various calibration methods including zenith clear sky observation, standard meteorological radiosondes and total water vapour column have been investigated. A method to evaluate these calibration techniques has been proposed based on the variance weakening.

Keyword

Raman Lidar, Water Vapour, Calibration, Scattering Ratio, Water Monitoring, Upper Troposphere

1. Description of the Lidar implanted at the Haute-Provence Observatory

Raman lidar water vapour implemented at the Haute-Provence Observatory (43.9°N, 5.7°E, elevation 685m) operates on a routine basis at night. A Nd:YAG laser pulse at 532.1 nm is emitted vertically through the atmosphere at a rate of 50 Hz. The backscattered signals are collected by optical fibers mounted in the focal plane of a 4-telescopes mosaic of 0.5-m-diameter each and transferred to the optical ensemble. The parallax design (emission-reception axis of 0.6 m) of this lidar exhibits a dead altitude zone from the ground up to 2-3 kilometers as a consequence of the small field of view. The Raman shifted lines H2O (660 nm) and N2 (607 nm) are separated with a dichroic mirror and are detected by means of photomultiplier tubes operated in photo-counting mode. Counts from 8000 shots (~2 min 40 s) are preaccumulated in 75-m (0.5 µs) bin intervals and stored to constitute the raw data.

2. Data analysis

The water vapor mixing ratio is based on the ratio of the H2O Raman (660 nm) and the N2 Raman signal (607 nm) as described by Sherlock et al. (1999) accounting the atmospheric differential transmission Γ(z) and the calibration coefficient C:

$$q(z) = C.\Gamma(z).\frac{S_{H_2O}(z)}{S_{N_2}(z)}$$

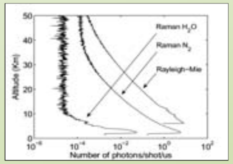
The optical thickness of cirrus is calculated in accordance with the Scattering Ratio profile (SR) which is determinated by the following expression:

$$SR = \frac{\beta_{aerosol}(\lambda,z)+\beta_{rayleigh}(\lambda,z)}{\beta_{rayleigh}(\lambda,z)}$$

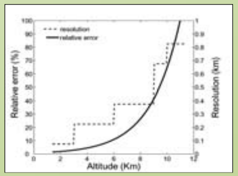
The optical thickness of cirrus, ζcirrus, is calculated in using a method similar to that described by Goldfarb et al. (2001) where ζcirrus can be expressed by the following expression:

$$\tau_{cirrus} = (LR).\sigma_{rayleigh}\int_{z_{min}}^{z_{max}} n_{air}(z).(SR(z)-1)dz$$

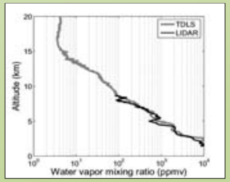
Where βrayleigh=σrayleigh.nair(z), and nair(z) air density number are calculated by the MSISE-90 atmospheric model. A Lidar Ratio (LR) of 18.2 sr (Platt and Dilley, 1984) is used, and σrayleigh(532nm)=5.7x10-32 m2 sr -1.



Example of Raman H_2O, N_2 and Rayleigh-Mie backscatter signals for the June 25th, 1999. The signals have been integrated over around 6 hours and correspond to the number of photons per shot per microseconds.



Mean relative errors (solid line) and vertical resolution (dashed line) as a function of the altitude. These results are shown for a temporal integration of 1 hour.

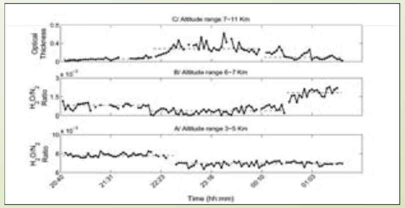


Lidar-TDLS intercomparison performed on June 20th 2000, the grey solid line represent the mixing ratio profile from balloon borne TDLS and the black solid line represents the mixing ratio profile from lidar

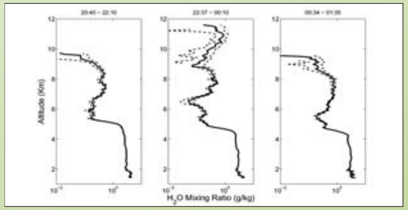
3. Data sampling

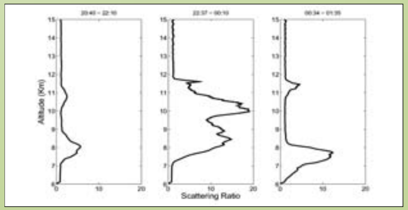
In order to get a reasonable compromise between accuracy and atmospheric variability, the proposed method consists of adjusting the integration time with the discontinuity of the flow sounded. To achieve this goal, the series of the ratio of the raw data have been statistically investigated to identify discontinuities at several altitude heights.

The identification of discontinuities in the time series is based on the test of non-stationarity of the series due to a change in the dispersion. The procedure applied is an iterative method designed to research the multiple change-points in arbitrary values series. This method is based on the method of the non-parametric test.



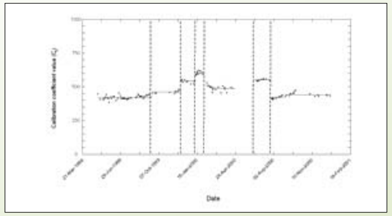
Vertical profiles of water vapour and scattering ratio obtained by lidar during the same night of measurements on May 28th, 1999. The 3 profiles correspond to 3 distinct periods when geophysical changes of large vertical scales have been found significantly unchanged (quasi stationary geophysical conditions).



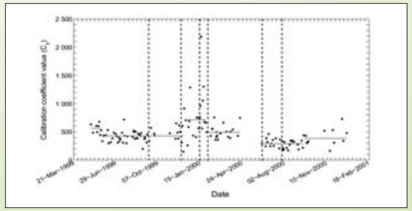


4. Analysis of calibration methods and comparison

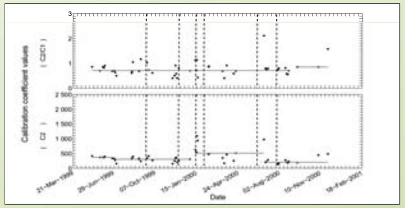
Calibration coefficient values (C_0) obtained from the calibration method using zenithal solar angle between 62-65°.



Calibration coefficient values (C_1) obtained by lidar/radiosonde calibration.

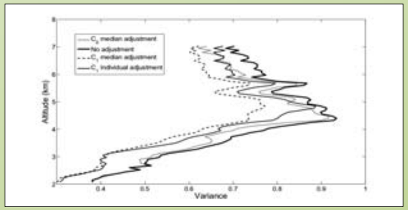


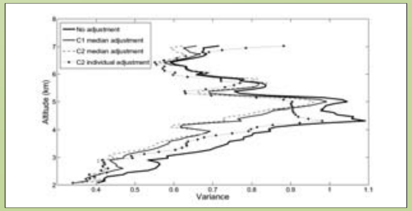
Calibration coefficient values obtained by the calibration method coupling radiosonde and total column H_2O.



Major instrumental changes for the period May 1999 – December 2000	
Date	Instrumental changes
13 Sep 1999	Emission modification and telescope adjustment
29 Nov 1999	Change of counting system
13 Jan 2000	Telescope adjustment
31 Jan 2000	New alignment in the optical box
09 Jun 2000	Telescope adjustment
26 Jul 2000	Optical fiber change (0.9 to 1.5 mm)

To perform a more quantitative estimate of the calibration coefficients, the lidar water vapour mixing ratio calibrated with 3 methods, in the altitude range 2-7 km has been calculated. The signals observed result of the contribution of geophysical variability with various superimposed errors associated to the instrument and data processing. Both contributions being independent, we define the observed variance as the sum of the geophysical variance and the variance of error.





Conclusion

The proposed methodology relating to the integration time seems to be a good compromise between the accuracy of lidar profile and the variability of water vapor. Also the better results for the calibration have been obtained from the method using total column which tends to improve the radiosonde method. However zenith clear sky observations method seems to be better for the detection of instrumental changes. The method seems to be a good compromise in the improvement of the calibration.

Cargèse International School (COST Action ES604) Water Vapour in the Climate System (WAVACS), Cargèse (France), 14-26 September 2009