

Review: An incoherent broadband cavity-enhanced absorption spectrometer for simultaneous NO₃ and N₂O₅ measurements, integrated into a NO_y instrument suite: characterization and first field deployment

General Comments

In this paper, a new field instrument (NO_yBO_x) is presented which combines several commercially available instruments to measure NO, NO₂, and NO_y with custom-built, IBBCEAS cavities to measure NO₃ and N₂O₅. The instrument is well characterised and described and data from its maiden campaign is presented. The paper is well structured and data are presented clearly. Overall, I find this paper to be worthy of publication.

Specific comments

1. In Section 2.2.4 it is stated that “absorption features from NO₂, H₂O and O₃ are also present; however, given their atmospheric abundances and cross-section magnitudes, only NO₂ and H₂O contribute meaningfully to the retrieved absorption”. This is misleading. The Chappuis band of O₃ in the region analysed can have an equivalent or even greater overall absorption than the LOD of NO₃ under realistic conditions (20-100 ppbv). O₃ is not detectable under these conditions because the “shape” of the spectrum in this region is well approximated by a polynomial and thus absorption from O₃ is indistinguishable from the polynomial correction $p(\lambda)$. If the absorption spectrum of O₃ were more structured in this region but abundances and cross-section magnitudes remained the same, then O₃ interference would be visible. As it reads now, the passage suggests that very little light is absorbed by O₃, which is not the case; the passage should convey that the shape of the spectrum plays the key role.
2. Section 2.2.1 states that the LEDs used for the NO₃ and N₂O₅ channels are cooled at different operating currents of 650mA vs 1150mA. What is the reason for such a large discrepancy; are the LEDs operated at different powers? Thermal regulation to $\pm 0.01^\circ\text{C}$ seems unrealistically good, is there data to support this?

3. There is significant effort given to constraining the role of water in the retrieved spectrum. This is a difficult problem for IBBCEAS systems under the stated conditions. In Fig. 2 c) H_2O is given as α while NO_3 & N_2O_5 are given as σ . Are the retrieved water concentrations from α quantitative, in other words, is the $\text{RH} = 31.8\%$ shown in Fig. 2 b) derived from the spectrum or an independent hygrometer or similar device? If it was recovered from the water contribution to the IBBCEAS spectrum, then how was this done? How do retrieved water measurements compare with hygrometer RH measurements?
4. How well do NO_2 concentrations retrieved from the IBBCEAS system quantitatively agree with the CAPS measurements in NO_yBO_x ? Since retrieved NO_2 is important for accurate NO_3 retrieval, it would be enlightening to see this data. Can NO_2 concentrations be fully constrained by the CAPS instrument? This is an advantage of an integrated instrument that should be elaborated upon.
5. Is the temperature used in Fig. 9 b) the ambient temperature of the sample air before entering the instrument or after leaving the unheated cavity? What is the internal temperature of the instrument / gas stream within the cavity? It is suggested in Section 3.5.1 that degradation of the NO_3 signal in the Allan plot is “likely reflecting the absence of temperature regulation in the NO_3 cavity”. More information on the internal temperature of the instrument is required to support this claim. It is also important for understanding the “true” ambient concentrations of NO_3 and N_2O_5 ; if the gas gets warmed up in the inlet and within the instrument, it will have an effect on the measurement by disturbing the thermal equilibrium.
6. Regarding the “calibration” mode outlined in section 2. It is stated that during calibration “excess gas of the NO_3 and N_2O_5 channels is vented through sampling inlets” with no mention of scrubbing. Is it correct that some flow of 800 ppbv NO_2 is vented into ambient air through the NO_3 / N_2O_5 inlet? Is the performance of the MFC at the exit of the cavity affected by the high levels of NO_2 flowing through it?
7. Regarding Fig. 1
 - a. Why is there a tee fitting at the junction between the inlet, ZA / NO_2 gas, and the cavity for the NO_3 channel, but a 3-way valve in the same position in the N_2O_5 channel?

- b. What type of 3-way valves are used, and are they all the same? Do the valves switch between a mode where all ports are open and a mode where one port is closed or do the valves switch between two modes where a different port is closed (i.e. all ports cannot be open at the same time)? It would be helpful to state this explicitly. It would also be helpful for understanding the diagram to mark on the diagram which outlets/inlets are common / always open.
- c. Are the valves in the sample line made of an inert material or coated in one?

Technical Corrections

Fig. 9 b) legend should read Burkholder **et al.**

Fig. 9 c) has an inconsistency between the labels and the legend. Either NO_3 should be black on the axis label and included in the legend or there should be no legend and the $\text{N}_2\text{O}_5 + \text{NO}$ axis labels should be coloured appropriately.