Atmos. Meas. Tech. Discuss., 7, C300–C311, 2014
www.atmos-meas-tech-discuss.net/7/C300/2014/

Atmospheric Measurement Techniques
Discussions

Interactive comment on "A high-resolution oxygen A-band spectrometer (HABS) and its radiation closure" *by* Q. Min et al.

Anonymous Referee #4

Received and published: 28 March 2014

The present paper reports on a novel high resolution oxygen A-band spectrometer (HABS) and its performance in direct sun and zenith scattered light observations. Comparisons of the observations with radiative transfer calculations are made. It is known that oxygen A-band measurements may provide novel information on the radiative transfer under clear and clouds skies, in particular of the photon path length distributions. Such measurements are highly valuable when complementary measurements, c.f. from a Lidar, cloud radar and microwave instrument, of aerosol and cloud properties are available. In this respect the present manuscript may be suitable for publication in AMT.

However, I feel much discomfort in answering the question to what readership the paper might be suited (beyond for the authors and some closely collaborating colleagues),

primarily since

A. The provided information is at places rather slippery, without further details being provided (see below).

B. The authors do not really attempt to connect their research to the research (and knowledge) of other research groups working in the field of atmospheric UV/vis/nearIR spectroscopy, a statement which becomes most visible in the lack of proper referencing in the manuscript (of which some examples are given below).

C. The manuscript is not carefully written (as it is detailed below), neither with respect to the provided information, the English, and occasionally with respect to the 'inner' order or flow of arguments. For the latter it is necessary to careful consider the logical structure inherent in scientific arguing and writing: 1. provision of the necessary information, 2. measurements and observations, 3. results, 4. discussion of the results, 5. conclusion, and not has it often happens in manuscript to arbitrarily permute the required order (for examples see below).

Accordingly I recommend a major revision, or if the time-lines can't be met a resubmission of the manuscript, i.e. a rejection of the present manuscript.

1. Major comments:

My major concerns are the following

1.1. Page 1028, line 17 and elsewhere in the manuscript: It is certainly necessary to include rotational Raman scattering in the RT modelling of high resolution skylight spectroscopy, since it is known that Raman scattering occurs in 3 to 5% of the Rayleigh scattering events, depending on the type of molecules involved. Addition since diffuse skylight is due to a varying fraction of Rayleigh and Mie scattered light, Raman scattering is certainly a contributor to the stated discrepancy between the modelled and measured oxygen a-band spectra in diffuse skylight.

1.2. Throughout the discussion of possible causes on the discrepancy of modelled and measured spectra one could make use of changes in the optical density of the detected solar Fraunhofer lines, since it may indicate

(a) The amount of spectrometer stray-light and how well the detector offset and noise are removed (of which nothing is mentioned in the manuscript)

and

(b) in as much Raman scattering may play a role (see point 1.1), since the Fraunhofer lines would be partly filled-in the measured as compared to forward modelled spectra assuming that Raman scattering is not (or not properly) accounted for in the RT modelling.

Further water vapour lines of the $3\nu + \delta$ band, which start to become prominent (OD > 10-3) for wavelength larger than 768 nm, are not mentioned in the discussion of the spectra. So this point needs clarification?

1.3. The investigation of the polarization depend optical depths of the various solar Fraunhofer lines (see your Figure 7) would further allow you to disentangle the spectrometer stray-light from the incorrect correction of the detector offset and noise, and/or the amount of Rayleigh scattering into the Cabanne and rotational Raman lines as well as light due to Mie scattering. While one could argue that a discussion of the latter process may subject to a forthcoming study, a discussion of the former processes may certainly form a constitutive part to properly characterize the instrument.

1.4. Findings in support of major comment C:

a. Page 134, line 15: Quoted 'Figure 6a shows HABS measured oxygen A-band direct beam spectra and the related zenith diffuse spectra under clear day situations. Figure 6b shows two HABS measured oxygen A-band zenith diffuse spectra for thick clouds and cirrus clouds, respectively. It is clear that the absorption lines are individually resolved and they have very large dynamic range. This indicates that the HABS measured oxygen A-band spectra have the capability to retrieve the photon path length and

thus retrieve the vertical profiles of cloud.' The last 1.5 sentences (....and they have very large dynamic range. This indicates that the HABS measured oxygen A-band spectra have the capability to retrieve the photon path length and thus retrieve the vertical profiles of cloud. ...) should be moved to the conclusions, once the content of statement is arguable made more clear.

b. Page 1035, lines 24 to 25, move the contents into the introduction. Quoted 'However, calculating oxygen absorption optical depth profiles with LBLRTM is also very time-consuming (more than 5 h for the entire oxygen A-band by a fast PC). Because the atmospheric structure is always changing with time, frequent recalculation of the oxygen absorption optical depth profiles is required. To reduce the computational cost, it is necessary to develop a fast method to recalculate the oxygen absorption optical depth profiles accurately.'

c. Page 1038, lines 15 and 16, move to the conclusions: Quoted 'The difference of normalized radiance between observation and simulation is very small.'

2. Minor comments (technical comments)

2.1. Page 1028, line 9 and again page 1030 line 27 (a comment in support to my statement A): The stated resolution of 0.16 nm (and on page 1033, line 27 the authors contrarily mention, that the instrument function - what is the instrument function - is 0.016nm), can't be correct, since

a. As indicated by the insert of Figure 4, the FWHM (full width half maximum) resolution is 3 pixels. According to Nyquist-Shannon sampling theorem, your spectra are largely under-sampled which may cause major problems for tiny spectral shifts (see below point 2.2). Now since the stated wavelength range of the spectrometer range is 759 nm to 769 nm, and the CCD camera has 1024 horizontal pixels, the dispersion is 10nm/1024 pixel or 0.0098 nm/pixel, and accordingly the FWHM resolution is 3 pixel/FWHM $\cdot$ 0.0098 nm/pixel = 0.0293 nm/FWHM. How does this relate to the stated resolution of 0.016 nm/or 0.16nm? Please clarify.

b. Also since the line width of the oxygen A band rotational line in the atmosphere are 3.5 to 4 pm (0.001 nm), a FWHM resolution of 160 pm (0.16 nm) would certainly be too coarse to resolve individual rotational oxygen A-band lines.

c. Further a FWHM resolution of 0.160 nm would also not be sufficient to squeeze out 4 to 5 pieces of information (on the radiative transfer) from oxygen A-band measurements, as you state – without further proof – in the manuscript. So please clarify and correct accordingly.

2.2. Page 1028, line 16 and elsewhere in the manuscript (a comment in support to my statement A): Since your spectra are largely under-sampled, let's argue what the requirements are for the wavelength stability. Assuming that for strong lines the relative difference is a (fair) 7%, and as indicated by the insert of Figure 4 the intensity drops by a factor of 2 for single pixel of wavelength shift, then the requirement for the wavelength stability is 7/100·1/2·0.0098 nm < 10-5 nm. So before arguing in the manuscript on any other possible causes of the differences between modelled and measured spectrum, you need to show that the wavelength stability is better than 10-5 nm.

2.3. Page 1028, line 10: For what wavelength distance from the center of maximum transmission the 'Out-of Band-Rejection' is defined?

2.4. Page 1028, line 23: What cloud properties you refer to?

2.5. Page 1031, line 1032: As demonstrated by Min and Clothiaux (2003), the direct beam measurements can be also used to construct the retrieval kernels directly. → As demonstrated by Min and Clothiaux (2003), the direct sun measurements can also be used to directly construct the retrieval kernels. What do you mean with retrieval kernels, clarify. In fact, including the reference of Rodgers (2000) would a little clarify matters here (see my comment B. and the comment in section 4.)

2.6. Figure 9, right panel: What is the unit of the aerosol extinction? Is it (1/km)? Please clarify.

2.7. Figure 10: What is the reason why the discrepancy between the modelled and measured oxygen A-band increases with increasing SZA?

2.8. Figure 11: Why there is kink in the normalized radiances for strong absorbing lines at around 2 air masses. What is the unit of the x axis, i.e. air mass?

2.9. Page 1028, line 15 and 16: How is the relative difference defined? Is it only the difference between modelled and measured spectrum for the whole spectral range, or only for the wavelength intervals where rotational lines of the oxygen A-band occur. Please clarify and explain?

2.10. Page 1031, line 15 to 16 and elsewhere in the manuscript: Because each pixel measures different portions of absorption spectrum, the spectrum shifting will bring in errors to the retrieval processes. What do you mean with this sentence? In fact, I can imagine what you like to express, but the sentence does not reflect the underlying physics (see comment 2.2).

2.11. Page 1033, line 17: The SNR is determined by both readout and Poisson noise terms -> The SNR is determined by both read-out and photon electron shot noise, the latter being Poisson distributed. In fact you could disentangle the read-out from photon electron shot noise from studying how the noise changes when co-adding individual spectra. So more information needs to be provided here.

2.12. Page 1036, line 20 Using three of them, we derive the three parameters (i.e., a0, a1, a2) in Eq. (7) for every wavenumber. Explain how you choose the 3 correct from the ensemble of the six model atmospheres?

2.13. Page 1039, line 29: The slight non-linear part is caused by strong oxygen absorption and by temporal variation of atmospheric profiles (e.g., temperature profile, pressure profile, and aerosol profile). I doubt your statement and accordingly reconsider the physics and look for a more consistent explanation.

2.14. Page 1039, line 6: Quoted 'The combined measured spectra have the ability to remove or constrain the impacts of the instrument polarization performance.' Please describe briefly how?

2.15. Page 1030, line 16: This could be caused by two factors: (1) the error of instrument slit function measurement and oxygen absorption line parameters and (2) Raman scattering (effects). See comment 1.1

2.16. And so on..

3. Some (but by far not all necessary) recommendations to improve the English

The English of the manuscript is rather slim, and since native English speakers are co-authors of the manuscript, it is highly recommended they may carefully proof-read the manuscript prior any resubmission. Below I list some - but by far not all necessary - improvements.

3.1 At many places the tenses change from 'simple presence' to 'simple past' without further motivation. In order to make it clear what is meant, here come some of many examples

a. page 1031, line 13 to 19: Quoted 'As a high-resolution spectrometer, the instrument is sensitive to the environment temperature, which can result in the spectrum wavelength shifting (Li and Min, 2012). Because each pixel measures different portions of absorption spectrum, the spectrum shifting will bring in errors to the retrieval processes. To alleviate these errors, a temperature controlling system was implemented into the instrument, which consists of a temperature controller, temperature sensors, fans, heaters, and a water cooling subsystem (not shown here).'

b. Instead of: Quoted 'In order to alleviate these errors, a temperature controlling system is (instead of was) implemented into the instrument.'

So much more consistent were to use the tense 'simple presence' when describing the instrument, model, et cetera, and only to use simple past when explicit times are provided.

c. Page 1033, line 1: Quoted 'This will modulate the spectrum shape of the incident light, which can be presented by "filter function". . ..instead of . . ... This modulates the spectrum of the incident light, which can be presented by "filter function"'

d. and so on

3.2 Non appropriate qualifiers (adverbs, or adjectives):

a. page 1037 line 5 and elsewhere in the text: change from: . . ... super high spectra resolution radiance → high spectral resolution radiance .. and please skip 'super' because it is a non-scientific qualifier to something (i.e. slang) and second consider the proper English grammar in two following adjectives. Also with respect to the mentioned (FWHM) resolution of 0.160nm, (which is certainly wrong, see comment 2.2), the under-sampling of the present instrument, the natural (atmospheric) line width of the rotational lines of the oxygen A-band and the spectral resolution of instruments used in previous studies, the qualifier 'super' is not at all justified.

b. Page 1038, line 5: Quoted 'As shown in Fig. 8a, MFRSR measurements indicate that 26 July 2011 was a good clear day for radiation closure study of HABS.' What is a 'good' clear day in scientific terms?

c. Page 1037, line 24: Quoted 'As stated previously, the measured HABS slit function shows very good local monochromatic property.' Explain what is a 'good local monochromatic property'? (see also comment 3.3) Accordingly, it is recommended to refrain from the usage of a non-English slang, or non-scientific qualifiers (c.f., in adverbs or adjective) – in particular if not justified - throughout the manuscript.

3.3 Further I find it very irritating if the same thing gets different names in a manuscript. Examples are

a. Page 1028, Line 10: Out-of-band-rejection which is called on page 1031, line 27 radiation outside the band

b. Page 1033, line 9: Slit function which is called on page 1031, line 3 instrument function(s)

c. And so on..

3.4 Typos

a. Page 1031, line 28: fill up -> fill-up

b. Page 1038, line 9: the sonde balloon –> the balloon sonde

c. Page 1045, line 13: Kruz -> Kurz

d. And so on

3.5 Some specific (but by far not all) comments to the English (from -> to)

a. Abstract: The HABS has the ability to measure solar direct-beam and zenith diffuse radiation through a telescope automatically -> By using a single telescope, the HABS instrument may subsequently measure the direct solar and the zenith diffuse radiation.

b. Abstract: To evaluate the spectra performance of HABS, a HABS simulator has been developed by combing the discrete ordinates radiative transfer (DISORT) code with the High Resolution Transmission (HTRAN) database HITRAN2008. -> For the spectral retrieval of the HABS measurements, a simulator is developed which combines a discrete ordinates radiative transfer (DISORT) code with the High Resolution Transmission (HITRAN) database HITRAN2008.

c. page 1031, line 15 to 16 and elsewhere: Because each pixel measures different portions of absorption spectrum, the spectrum shifting will bring in errors to the retrieval processes. change . . ... the spectrum shifting -> A shifting wavelength-mapping of the spectrum . . ...

d. page 1030, line 20: a high performance charge-coupled device (CCD) assembly -> a high performance charge-coupled device (CCD) detector (and add the type and/or explain which one?)

e. page 1030, line 22: the alt-azimuth tracker -> the elevation-azimuth sun tracker

f. page 1030, line 26: the direct beam measurements can be used to assess instrument functions and absorption line parameters with simple Beer's law -> the direct beam measurements can be used to assess instrumental features (mention which one?) and absorption line parameters.

g. Page 1031, line 1032: As demonstrated by Min and Clothiaux (2003), the direct beam measurements can be also used to construct the retrieval kernels directly. -> As demonstrated by Min and Clothiaux (2003), the direct sun measurements can be also used to directly construct the retrieval kernels.

h. Page 1035, lines 4 to 6: The issues about HABS polarization measurements will be evaluated and analyzed in detail in another paper about the HABS in the near future. -> In more detail the HABS polarization measurements will be evaluated, analyzed an discussed in a forthcoming paper.

i. Page 1036, line 13: Therefore, to simulate a high-resolution measured spectrum, we need to make radiative transfer calculations at much higher spectral resolution in a line-by-line domain. A question: . . ...higher with respect to what? . . . so there is a wrong comparative.

j. Page 1037, line 27: At the peak center of slit-function -> At the slit function maximum

k. Page 1038, line 23: In this study, the normalized radiances at five wavelengths are chosen for analysis (shown in Fig. 11b). -> In this study, the normalized radiances at five wavelengths are chosen for the analysis (shown in Fig. 11b).

l. Page 1038, line 25: In general, the HABS direct-beam measurements and model simulations are basically consistent with each other at different air masses.–> In general, the HABS direct-beam measurements and model simulations are basically consistent with each other for different air masses.

m. In particular, at big SZAs, the simulated zenith diffuse radiance at the absorption line centers tends to be slightly smaller than observed one. This could be caused by Raman scattering effects. -> In particular, for large SZAs the simulated zenith diffuse radiance at the absorption line centers tends to be slightly smaller than the observed one.

n. Improvements to the legends of the Figures

Fig. 2. The schematic of the high-resolution oxygen A-band spectrometer (HABS) optical system. -> Optical set-up of the high-resolution oxygen A-band spectrometer (HABS).

Fig. 3. Spectrum response ratios to the lamp GS0937 at different channels (i.e., open, diffuser, and 4 polarizers with different orientations) of the filter wheel. -> Fig. 3. Spectral response for different optical channels (i.e., open, diffuser, and 4 polarizers with different orientations) measured with a GS0937 lamp.

Fig 4. Slit function of high-resolution oxygen A-band spectrometer (HABS) with a 1.55 pixels FWHM. The inner figure is an expansion of the slit function in linear scale. -> Fig 4. Slit function of the high-resolution oxygen A-band spectrometer (HABS): The insert indicate a FWHM resolution of 1.55 detector pixels.

Fig. 5. Estimated signal-to-noise ratio (SNR) at 19:13 (GMT) on 14 June 2011 at Howard University Beltsville site. -> Fig. 5. Estimated signal-to-noise ratio (SNR) for a direct (or is it a diffuse light?) spectrum taken at Howard University Beltsville site at 19:13 GMT on 14 June 2011. Here the question how you defined S/N and how is it estimated? Please clarify.

Fig. 6. (a) HABS measured direct beam spectra and zenith diffuse spectra at oxygen A-band under clear day situations at solar zenith angle of 72o. (b) Two HABS measured zenith diffuse spectra at oxygen A-band under different cloudy situations at solar zenith angle of 22o. -> Fig. 6. HABS measured oxygen A-band spectra for the direct solar beam at SZA = 72o (upper panel) and diffuse zenith spectra (lower panel) under clear

skies for SZA 22o for different cloud optical depths.

and so on. . .. . .

4. Additional References

a. Page 1034, Line 1 – 6: Add the following reference: Platt, U. and J. Stutz, Differential Optical Absorption Spectroscopy: Principles and Applications, Springer Verlag, Heidelberg, ISBN 978-3540211938, 597pp, 2008. for the effects of shifts in the wavelength mapping, under-sampling, et cetera on the S/N.

b. Page 1031, line 1032: for inversions you need to reference to: Rodgers, Clive D. (2000). Inverse Methods for Atmospheric Sounding: Theory and Practice. World Scientific.

c. . . ...

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