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Atmospheric Measurement Techniques
Discussions

# *Interactive comment on* "Upper-troposphere and lower-stratosphere water vapor retrievals from the 1400 and 1900 nm water vapor bands" *by* B. C. Kindel et al.

**B. C. Kindel et al.**

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1. The measurements made during dive 2 of SF2-2013 were certainly affected by the presence of cirrus clouds (e.g., see the NASA ATTREX CPL data, and the data from other spectrometric measurements aboard) and in fact you are seeing traces of an ice absorption between 1450 to 1600 nm. Accordingly, ice absorption needs to be included in your retrieval, and mentioned in the manuscript.

Response 1. The presence of ice absorption in the SSFR spectrum is a good catch by the reviewer. The method outlined is, as the second reviewer points out, best used in



clear sky cases. However, the cloud must have been optically thin, and the agreement between the NOAA in situ and SSFR water vapor retrieval is quite good, in fact better than some of the other cases. More importantly, this example illustrates one excellent method for screening for the presence of clouds in the spectra without having to resort to other measurements (that may or may not exist alongside the SSFR for a given flight experiment). We have included some text pointing out the evidence for cloud contamination, the agreement despite the contamination, and the potential of these wavelengths in identifying cloud contamination. Lines 262-270.

2. Unlike mentioned in the final paragraph, the O2 (1g(0) 3g-(0)) absorption at 1270 nm and the CO2 (21o2, 00o0) absorption band (at 1580 to 1620 nm) could be used to validate the assumptions made in RT calculations. This might be relevant for example to check for the assumptions made regarding the extra-terrestrial solar irradiance and the aerosol concentration and their type in the air column between the aircraft and TOA. This issue needs to be more carefully addressed.

Response 2. This is a good suggestion and some text has been incorporated into the text about this. Lines 391-395.

3. The manuscript lacks some crucial information on the assumption on the aerosol type and profiles used in the RT model. To provide such information appears rather necessary, since in the near-R spectral range, Mie scattering – though small in stratosphere – becomes more important as compared to Rayleigh scattering.

Response 3. The reviewer is correct that the aerosol scattering becomes more important in the NIR relative to molecular scattering, but both are very small at these wavelengths and altitudes. In MODTRAN, the aerosol (Mie) extinction is ~10-4 (background volcanic stratospheric aerosol) compared to the water vapor absorption (1-3%). It might become a concern for a large volcanic event that put large amounts of aerosols into the upper atmosphere and that caveat has been included in the text. Lines 77-80 and lines 227-228.

Minor comments:

1. Abstract, third line: correct to ‘Solar Spectral Flux Radiometer’ (SSFR)

Response 1. SSFR has been included in the Abstract. Line 19.

2. Section 2, third paragraph: Here, a sentence needs to be included in the manuscript for which spectral resolution the calculations were made.

Response 2. The spectral resolution of the plot is at the SSFR resolution and sampling, the details of which are given in Section 3 describing the instrument. This is now noted in the caption to figure and the text. Lines 102-103

3. Section 7, equations (2) and (3): Since at large water vapor columns, the water vapor bands starts to become saturated, you need to mention an upper limit of the validity of the linear equations (2) and (3) of the water column as a function of water vapor absorbance.

Response 3. The reason the linear approximation made in this section was to formulate a simple method to convert measurement uncertainties into water vapor amounts (something meaningful to the reader). It is correct that with increasing water vapor amount absorption becomes nonlinear and this has been noted in the text along with the reason for the non-linearity: lines within the band become saturated and increasing absorber amount is no longer linear with absorptance. Lines 335-338.

4. Section 7, last paragraph: An absolute calibration of the radiometer would not be necessary if you were to inspect ratio of measured spectra, for example a ratio of a spectrum taken at the upper levels vs a spectrum taken at the lower levels of the Global Hawk cruise, because then you could use a differential approach to interpret the measurements. In this case, you would also not need to refer your measurements to the ‘Kurucz’ TOA solar irradiance spectrum (which in fact is not a TOA solar irradiance spectrum, but a spectrum taken the Kitt Peak observatory, from which residual atmospheric absorption have been a more or less well removed).



Response 4. The differential approach is what we have used here and as the reviewer points out an absolute calibration was not necessary. The SSFR data are radiometrically calibrated because the instrument is typically used for energy budget studies, not gas retrievals as was done in this work. The calibration makes no difference to the work presented in this paper; it is simply a multiplier that drops out in the ratio when calculating transmittance. However, it is essential to the proposed technique outlined in section 7 to retrieve integrated water vapor from the aircraft flight level to TOA (not a transmittance change between two flight levels) because it depends on matching the TOA solar spectrum at wavelengths essentially free of atmospheric extinction and normalizing these to unity. By matching these wavelengths and producing the correct shape (spectral response) as well as removing the effects of laboratory water vapor, a measurement of water vapor should be possible without flight level changes.

5. Section ‘results’, last but one paragraph: Since in section 3 you mention that the absolute radiometric uncertainty of the instrument is 5%, please demonstrate how the radiometric precision of the instrument can be 0.1%, as stated in the section results. Arguments need to be developed via inspecting the spectrometer straylight, the detector noise as a function of the number co-added spectra, detector well-depth, et cetera,

Response 5. The precision (measurement-to-measurement repeatability) has in the laboratory been found to be about 0.1%. In the wavelengths nearly free of atmospheric extinction and good solar signal (e.g 1300 nm), the repeatability of the ATTREX measurements is also about 0.1% (Figure 9). This is perhaps the best estimate of the precision because it is a “flight value” not a “lab value”, and in fact, the two agree. The estimated absolute accuracy, about 5% is something different, and is relative to the “true” value of the irradiance, something unimportant to this work because the calibration drops out in the ratio.

6. Section ‘summary’, last paragraph: You write that the instrument zenith looking, what is field of view. If the field of view is 2, then it would be more appropriate to use the notation ‘upper hemisphere’.

Response 6. We have reworded this to "downwelling airborne solar spectral irradiance". Lines 382-382.

Interactive comment on Atmos. Meas. Tech. Discuss., 7, 10221, 2014.