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Atmospheric Measurement Techniques Discussions

Interactive comment on "The CU 2D-MAX-DOAS instrument - part 2: Raman Scattering Probability Measurements and Retrieval of Aerosol Optical Properties" *by* Ivan Ortega et al.

Anonymous Referee #2

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Ortega et al., describe derivation of aerosol optical depth and Henyey-Greenstein asymmetry factor from solar almucantar measurements (-170° to 170°, 5° steps) of Rotational Roman Scattering probability. The method applies DOAS technique to hyperspectral intensity measurements to derive differential RSP in 426 – 440 nm window and therefore does not require absolute radiometric calibration. The authors present radiative transfer simulations at 430 nm using Monte Carlo model to demonstrate sensitivity of the RSP to AOD, H-G asymmetry factor, aerosol profile, relative solar azimuth angle, and solar zenith angle. They conclude that RSP is independent of the aerosol profile and has low dependence on single scattering albedo and surface reflectivity. On the other hand, RSP has high sensitivity to total AOD and H-G asymmetry factor

especially at small RSAA, small AOD and large SZA. Based on these simulations they develop a method to minimize difference between retrieved (426 – 440 nm) and simulated RSP at 430 nm. Direct sun spectrum is used as a reference Fraunhofer spectrum to minimize amount of RPS in the reference spectrum. RSP in the reference spectrum is derived from Langley plot analysis of the zenith and direct sun spectra. The method is applied to 2 days, one with low and one with high AOD, during TCAP filed campaign (1 July – 13 August 2012). The retrieved AOD are compared to co-located measurements by CIMEL, MFRSR, and HSRL-2. Reasonable agreement in diurnal variability is achieved between CU 2D-MAX-DOAS, CIMEL, and MFRSR. The method is well described and the paper is well organized. I recommend publishing the paper after some modifications.

Major comments:

1. One of the main assumptions of the method is that solar almucantar measurements of RSP are independent of aerosol profiles based on the simulations at SZA 35° and 70°. This might not hold for all SZA, all G-H asymmetry factors and SSA, and especially more realistic aerosol phase functions. I would recommend expanding the sensitivity studies to aerosol profiles to include 20°, 35°, 70°, 80° and 85° SZA for G-H asymmetry factors 0.64 and 0.72 and SSA 0.85 and 0.98.

2. Please discuss the effect of G-H phase function approximation on the AOD retrieval compared to a more realistic Mie phase function for different aerosol types?

3. I think that error estimation is overly optimistic especially at small SZA and small RSAA when dRSP are very small and "close" to the reference spectrum. The change in dRSP and its error do not change linearly with AMF especially for dAMF<0.5 from AMFref therefore the error in RSPref is larger then presented (0.0018). I think that more reasonable will be to either assume no RSP in the direct sun reference spectrum, or to model RSP with an RSP error equal to the RSPref itself currently derived in the paper (0.0044).

4. Method limitations need to be better stated: e.g. small AOD (how small?), clear skies (what is the tolerance to clouds), homogeneous aerosol profiles (what is the tolerance to heterogeneity), instrument FOV, instrument stray light, instrument SNR, etc.?

5. The field campaign lasted for over a month. Could the authors show all successful retrievals and show the linear correlations with other datasets based on all data not just 2 days?

Minor comments:

Line 93: described by an asymmetry factor g

Section 2.1: please describe the atmospheric conditions during TCAP in more detail (e.g cloud cover, aerosol types, vertical profiles). The authors probably have all the information to use Mie theory to calculate phase functions from other in-situ measurements.

Line 127: I suggest moving the sentences “To further... (Holben et al., 1998)” after point (3).

Line 154: What was the motivation to do almucantar scan at EA 45°. Have you analyzed these data?

Line 163: Why the authors did not use the integrating sphere to scan the sun in azimuthal and zenith direction to determine the precise position of the sun? Pointing accuracy and precise knowledge of the instrument FOV is important to characterize contribution of external stray light into the system. Please provide a figure in the supplement showing measured FOV of the instrument.

Line 180: Please clarify whether the authors use a single direct sun spectrum for the whole campaign, a single spectrum per day or for each solar almucantar scan its own DS spectrum. I believe it is crucial to have high pointing accuracy to minimize contribution of the scattered photons in the direct sunbeam measurement.

Line 197: Why did the users use Bogumil et al., 2003 NO2 cross section compared to Vandaele et al., 1998?

Line 210: Could the authors show one figure with the dRSP error vs dSCD and one with dRSP error vs RMS, and one RMS vs RSAA for SZA 35 and 70° in the supplemental material?

Line 266: could you please specify the dates when these layers where present and the results of the AOD retrieval from the MAX-DOAS instrument? I would think that such layers indicate heterogeneity of the air masses around the observations site and potentially intervene with the retrieval.

Section 3.2: Please explore the effect of aerosol inhomogeneity on the retrieval by performing RTM simulations. Section 3.2 describes the angular asymmetry factor but does not show how it impacts the retrieval at different SZA and AOD. The authors adopt AERONET almucantar screening at 20%. But it is not clear whether this is justified for RSP measurements.

Line 532: Fig 9 shows AOD430 = 0.6 at 14:00 LST.

Line 533: I am not sure I see this. SZA at 14:00 and 11:00 LST are about the same (30°) while AOD at 14:00 is 0.6 at 11:00 is 0.3-0.4. Despite a smaller AOD (therefore larger dRSP) at 11:00 the retrieval failed. Looking at Fig S6 Asymmetry Factor Parameter is about 10% around 11:00 which might be the reason for retrieval failure.

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