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Interactive comment on "CO profiles from SCIAMACHY observations using cloud slicing and comparison with model simulations" *by* C. Liu et al.

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This paper applies the cloud slicing method to CO observations from SCIAMACHY. Cloud slicing has been used previously to derive information about tropospheric ozone. While the use of the cloud slicing approach for CO observations is new and very interesting, the paper leaves open several fundamental questions that are critical to the analysis of cloudy data at CO-affected wavelengths.

Major points:

1. There are significant questions related to the interpretation and use of the effective

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cloud fraction derived at wavelengths near the oxygen A-band and applied at CO wavelengths. The authors reference two papers on the the FRESCO algorithm. Please see also Stammes et al. (JGR, 2008). Within the context of the mixed Lambertian cloud model used in many trace-gas retrieval algorithms, the effective cloud fraction, f_c, is the fraction of a hypothetical Lambertian cloud with 80% reflectivity that produces the radiance that is observed. Studies have shown that this model also well reproduces the amount of Rayleigh scattering and absorption that is observed. The clear sky fraction (in this model context) is then (1- f_c). However, to mix clear and cloudy air-mass factors or atmospheric column values, one should use the so-called cloud radiance fraction (see e.g., Veefkind et al., IEEE Trans. Geosci. Rem. Sens., 2006, Joiner et al., ACP, 2009) that is typically higher than the effective cloud fraction. This is alluded to on p. 11663 where it is stated that "the signal from the clouded part usually still dominates the measured spectra, which thus mainly contains information from the atmospheric above the cloud" (note the typo there).

It appears that the authors are treating the PVCDs (not well defined in the paper, but understood to be the "observed" slant column normalized to a vertical column in the presence of clouds, including partial and thin clouds) as if this were the PVCD above the cloud pressure. This is equivalent to the assumption of a cloud radiance fraction of unity. While cloud radiance fraction over the dark ocean of near unity may be a good assumption, it is not clear that it is the case over land. The cloud radiance fraction needs to be computed, and the implications of the assumption of cloud radiance fraction equal to unity should be evaluated. Since land surface reflectances around 2.3 microns are not near zero, the cloud radiance fraction will not be unity over land. The authors are using data with effective cloud fractions down to 10%, so this needs to be carefully examined. The differences in PVCDs between effective cloud fraction cutoffs of 10 and 40%, shown in Fig. 2, appear to be quite significant. This is why Ziemke et al. in several papers apply the cloud slicing approach with only very high effective/radiative cloud fractions (see e.g., Ziemke et al., 2009).

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If the goal is to use more data to produce global coverage, a different approach may be needed. For example. Joiner et al., (ACP, 2010) attempt to account for cloud shielding effects in partly cloudy conditions in the analysis of ozone column measurements. They show that if one assumes a well-mixed troposphere, the concept of an effective scene pressure can be used (i.e., the surface and cloud pressure are weighted appropriately by the cloud radiance fraction at the appropriate wavelength). They applied this approach to ozone data and use ozone sondes for validation, showing excellent results overall for tropospheric ozone.

2. It is not clear that the mixed Lambertian-equivalent reflectivity (MLER) cloud model can be applied at the wavelengths relevant to CO retrievals. The assumptions in this model begin to break down in the near-IR where cloud absorption becomes an issue. There is a statement on p. 11663 that "within the spectral range of the CO analysis clouds are not as bright as in the visible spectral range", but the implications of this are not investigated. It is not clear that the cloud pressure (or the cloud radiative fraction) derived from the O2 A-band is applicable at CO wavelengths, because photon path lengths (and cloud single scattering albedo) are different in the CO vs O2-A band wavelengths, see e.g., Platnick (JQSRT, 2001). In order to convince a reader that the cloud slicing approach with FRESCO is applicable at CO wavelengths, simulations over a wide range of conditions should be conducted. Note also that we refer to the cloud pressures derived in the VIS and UV as "cloud optical centroid pressure" - see also Vasilkov et al. (JGR, 2008), Ziemke et al. (JGR, 2009), Joiner et al. (AMT, 2010 and AMT, 2012).

3. Validation is a necessary exercise that should be conducted as well as possible in order to establish whether the approach is working properly. There is a wealth of CO profile information available from MOZAIC aircraft measurements at landing and takeoff sites around the world. In ozone work, many comparisons to ozone sonde data have been made and extrapolated stratospheric column data have also been compared with independent measurements (see e.g., Ziemke et al. ACP, 2009). Similar extrapolation

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of the results shown here may lead to unrealistic estimates of stratospheric column CO and that would leave the reader to question the validity of the results. Validation should be conducted before model comparisons in order to establish the relevancy of such comparisons.

4. Justifications as to why further analysis is done using PVCDs instead of derived concentrations (or mixing ratio) do not make sense to me. If the results in terms of concentrations are unphysical, then the results in terms of the PVCDs are also unphysical, they are just less obviously so. For example, if the above-cloud VCD is constant with altitude as it nearly is near the surface in several of the plots shown, that would imply a mixing ratio in those altitudes near zero. This would appear to be unrealistic, particularly over China near the surface, as shown in Fig. 4.

In summary, the results shown are physically unrealistic in many respects. Possible explanations as to why the approach may not be working as intended warrant further investigation.

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