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Interactive Comment

Interactive comment on "The potential of clear-sky carbon dioxide satellite retrievals" *by* R. R. Nelson et al.

Anonymous Referee #1

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The paper by Nelson et al. reports on a performance evaluation for "clear-sky" retrievals of the carbon dioxide dry-air mole fraction (XCO2) from solar backscatter satellite soundings. The evaluation is based on extensive simulations for an OCO-2 like instrument and on a real sounding ensemble from the GOSAT dataset. Essentially, a state-of-the-art retrieval algorithm (ACOS) is run in two variants: its standard full-physics variant and a simplified clear-sky variant neglecting scattering. If thorough screening of aerosol and cloud contamination is carried out, the performance of the clear-sky retrievals is found unexpectedly good which recommends investigating the usefulness of the clear-sky assumption in more detail.

The paper addresses a topic that is interesting for the future development of retrieval algorithms and the usage of XCO2 retrievals from GOSAT and OCO-2. The methods are robust and scientifically sound. The manuscript is well written. Therefore, I recommend publication in AMT after considering my comments below.

General comments:

1. While it is just to draw the optimistic conclusion that the clear-sky retrievals perform unexpectedly well compared to the full-physics retrievals, the pessimistic conclusion could be that the full-physics retrievals perform quite badly in accounting for particle scattering effects. Figure 1 might even support the pessimistic view that the full-physics method needs improvement. That thought should make its way into the discussion and conclusion section.

In that context, I would tend to criticize the following statement (abstract): "These results imply that non-scattering XCO2 retrievals are potentially much more accurate than previous literature suggests, when employing filtering methods to remove measurements in which scattering can cause significant errors." It is not the method "non-scattering" which is much more accurate. It will go wrong when there is scattering induced lightpath modification. It is rather the occurrence of clear-sky cases or the ability to filter for clear-sky which is unexpected.

2. Is there a particular reason why the clear-sky retrievals use both CO2 bands, 1.6 and 2 micron? Conceptually, using a single band could be beneficial for clear-sky retrievals if residual scattering is present. If there is residual particle scattering, its effect would be different in the 1.6 and 2 micron bands since particle scattering properties, surface reflection properties, and absorption optical depth are different for the two bands. Thus, using the two bands comes with the additional source of error that lightpath modification depends on wavelength. Previous studies preferred using the 1.6 micron band alone since aerosol effects are less pronounced (due to smaller CO2 absorption optical thickness) and since the surface is typically brighter than at 2 micron favoring the weight of the geometric lightpath. Probably, the IDP filter is efficient in removing the critical cases but, maybe, screening for clear-sky could be relaxed when using just one

band.

3. Why is the XCO2 RMS for the OCO-2 simulations (Fig. 4) typically a factor 2 larger over land than over the ocean? Could there be a non-vanishing influence of the prior?

4. The dry air column used for calculating XCO2 comes from different sources for the clear-sky and the full-physics method: for clear-sky, the meteorological (= true for the simulations) surface pressure is used, while retrieved surface pressure informs the full-physics XCO2. So, the full-physics XCO2 retrieval faces the additional complication that the surface pressure retrieval could go wrong. What is the assumed prior variance for the surface pressure retrieval? Does it make a difference (eg. in Fig. 4 and 8) whether full-physics XCO2 uses meteorological or retrieved surface pressure?

5. The evaluation for GOSAT is hindered by the fact that the true XCO2 is unkown. The manuscript uses two sources for true XCO2: TCCON and model data. Would the evaluation be different if the validation sources were considered separately? In other words, does figure 8 vary substantially if it was drawn for land-TCCON, land-model, ocean-TCCON, ocean-model separately?

6. The DOGO filtration minimizes the RMS of the XCO2 difference between retrieval and validation. Thus, the same level of throughput contains different individual soundings for the clear-sky and full-physics retrievals. Fig. 5 and 6 suggest that the sounding ensembles cannot be so different after all, at least for the OCO-2 simulations. How would performance evaluation turn out if the exact same sounding ensemble was compared (in particular for GOSAT)?

Technical comments:

P13042,L20 and P13043,L8: “These clear-sky retrievals are simple and highly linear”. Since Beer-Lambert’s law is exponential in the absorber concentration (and it cannot be linearized in a DOAS-like way due to large absorption optical thickness in the infrared), the forward model is non-linear even in the clear-sky case. Even if the retrieval used the logarithm of the measured radiance (instead of radiance itself), linearity (in absorber concentration) would require that the convolution (by the instrument function) and Beer-Lambert's exponential commute. They do not. If I get things right here, I would not call the forward model linear. But I would agree that aerosol fitting makes the forward model "more" non-linear.

P13045, L3 "molecular number density with respect to dry air" I guess, one can remove "with respect to dry air", number density is per volume.

P13048,L24: "used in the preprocessor" Do you mean "in the *GOSAT* preprocessor"?

Section 5: "Throughput" refers to the pre-filtered dataset (section 4.2), right? It might be obvious, but for me it would have been useful to read it stated at the beginning of section 5.

Figure 1: Please add information on coincidence criteria and the AERONET data type and source.

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 13039, 2015.