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Atmospheric Measurement Techniques Discussions

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

Anonymous Referee #3

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Nelson et al. investigate the application of XCO2 clear-sky retrievals to simulated Orbiting Carbon Observatory 2 (OCO-2) data and real Greenhouse Gases Observing Satellite (GOSAT) data. With sufficient pre- and post-retrieval filtering aimed at removing cloud and aerosol contaminated soundings, the clear-sky retrievals work about as well as full-physics (FP) retrievals on simulated OCO-2 data over land and oceans, and on real GOSAT data over land (but not for real GOSAT data over ocean).

To put this another way, the clear-sky retrievals usually work well on clear-sky soundings, but FP retrievals do better in situations with thin aerosol/cloud by accounting for scattering effects. Of course, neither retrieval algorithm performs well in cases of thick cloud and aerosol. In some sense, this is simply what one would expect, so the main conclusion is not ground-breaking, but such a study is still useful to help assess the

quality of clear-sky retrievals and confirm their validity, which could be important for fast processing applications related to OCO-2 or for future missions that could have orders of magnitude more data than OCO-2. For these reasons, this is a relevant scientific topic for AMT and in general the paper is reasonably well-written, but I would like to point out a few major issues with the study that should be addressed, along with a number of minor points.

1) The first major issue is that this is not a direct comparison between non-scattering (clear-sky) and scattering (FP) retrievals since the two approaches deal with surface pressure differently. It is retrieved in the FP retrievals by inclusion of the 0.76 micron band, but the clear-sky retrievals simply use the surface pressures from ECMWF. This difference is dismissed without much discussion or justification other than the fact that the O2 A band (0.76 micron) is the most sensitive of the three bands to cloud and aerosols.

2) The second major issue is the very different result that was obtained between the tests with simulated OCO-2 data and real GOSAT data over the oceans. The real data showed much larger errors than the simulation, which is almost enough to bring the main conclusion into question. Fortunately, the authors are transparent about this difference and their inability to explain it (which is appreciated), but my guess is that it suggests that their representation of aerosols in the simulated data is not realistic enough. Not enough details of the treatment of aerosol in their simulator are provided to specifically critique their method, but Figure 9 suggests that the problem is worst over the equatorial Atlantic Ocean, a region with substantial Saharan dust aerosols, although this would not explain the larger errors over other ocean regions. I suspect that their simulated aerosol types or quantities differ substantially from the real aerosols encountered by GOSAT.

3) The third major issue is that nearly 50% of OCO-2 observations over land will be made in glint mode, yet the paper does not deal with these observations at all. Of course, the authors would not be able to test their method for these data with GOSAT,

since it did not make land glint observations, but they still could have simulated land glint observations from OCO-2.

4) The fourth major issue is that since pre-retrieval and post-retrieval filtering are so crucial to obtaining a good quality clear-sky retrieval dataset, the authors have not given enough detail about the post-filtered observational coverage. Post-filtered coverage is never shown in any of the figures. What kind of spatial coverage is obtained from a 30% throughput applied to observations that have already been filtered with the A-band preprocessor and the IMAP-DOAS preprocessor (used with GOSAT data)? Perhaps Figure 3 could be changed to show the unfiltered, pre-retrieval filtered, and 30% throughput post-retrieval filtered OCO-2 spatial coverage in different colors. Something similar could also be done for GOSAT. If the filtering is very spatially-dependent, then readers need to know this.

Minor issues

P13041, L13 – A better phrase than "Carbon flux models" would be "CO2 inverse modelling systems" since they are talking about a system combining a model and measurements.

P13041, L18 – Should change to "sufficiently high accuracy and precision".

P13041, L19 – "0.5% ($\sim$2 ppm for CO2)" actually corresponds to XCO2 specifically and would not necessarily be the same for satellite CO2 profiles, so this should be changed to "XCO2".

P13042, L5 – The number of molecules of CO2 or the vertical column density can still be determined without detailed information about the light path. The light path is needed for any type of mole fraction like XCO2.

P13044, L13 – Similar to above, the "CO2 mole fraction".

P13044, L21-23 – Another reason (perhaps of equal importance) is that it is theorized that the column-averaged quantity minimizes the impact of vertical transport errors in

models, which become more significant at increasing horizontal resolutions.

P13045, L15 – It would be better to say "European Centre for Medium Range Forecasting (ECMWF) analyses".

P13045, L15 – Citations should be included for the ECMWF analyses and the CO2 prior (which sounds like the TCCON CO2 prior).

P13045, L25 – Are the ECMWF surface pressure uncertainties over complicated terrain at the OCO-2 pixel size known? These RMS differences would very likely exceed 1-2 hPa.

P13046, L8 – The authors should expand on what is meant by "Kahn 2b and 3b", with a couple of words to avoid forcing the reader to consult this reference.

P13047, L2 – Should replace "Afternoon-Train" with "Afternoon Constellation or A-Train".

P13048, L1-6 – It would be clearer to put each citation directly after the model description. Furthermore, referring to only one model by its contributor (David Baker) is inconsistent. It was the PCTM model.

P13048, L26-27 – It is important to explicitly state that some clear-sky observations are also removed by the pre-filtering methods, specifically many of those over snow and ice covered surfaces.

P13050, L4 – it would be very useful if the author would specify the four rules.

P13051, L11-12 – Have tests ever been done for the full-physics algorithm where surface pressure is not retrieved, but rather fixed to ECMWF, to retrieve clouds and aerosols?

Figure 6 – The histograms depict very little high optical depth data over land, relative to the data over the oceans. How realistic or representative of reality is this? A clarifying statement in the text would be desirable.

Figures 7 and 9 - Presentation of the errors on the TransCom regions here is not the best choice in my opinion (which relates to major point #4). These regions mostly correspond to surface vegetation regions over land and simply latitude/longitude boxes for the oceans, with the number of regions chosen based on a plausible target number of degrees of freedom for an in situ CO2 surface flux inversion. Cloud and aerosol effects would have different spatial impacts and likely occur with smaller spatial scale features that are not represented here. (TransCom also ignores the Mediterranean Sea and both missions observe in this region.) It is not explicitly stated that the grey regions have no data. White is a better choice for no data, which would require revising the color bar scheme for low RMS error. More importantly though, showing the RMS errors at some grid box scale (perhaps something like 2 degrees) would be more informative.

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