Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2020-366-RC2, 2020

Atmospheric Measurement Techniques Discussions

Interactive comment on "Analysis of 3D Cloud Effects in OCO-2 XCO2 Retrievals" *by* Steven T. Massie et al.

Anonymous Referee #2

Received and published: 4 November 2020

I believe this manuscript presents work that is worthy of publication. Most importantly, it estimates biases related to the presence of nearby clouds in satellite measurements of atmospheric carbon dioxide amounts. The methodology is reasonable and the presentation is generally good. Even so, I do have some significant concerns about the current version of the manuscript, and I recommend some major revisions. Please find my specific comments below.

Main issues:

1.

My main comment is about the attribution of retrieval biases to 3D radiative effects. I wonder if, in addition to 3D effects, other factors may also play significant roles in

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the analyzed biases. It is clear that the biases are caused by factors and processes related to the presence of nearby clouds, but perhaps not exclusively by 3D radiative effects. I wonder mainly about two other cloud-related factors. First, the surroundings of detected clouds are likely to contain some undetected clouds as well (subpixel-size clouds, cloud fragments detrained from larger clouds, remnants of mostly dissipated clouds, etc.). Second, aerosol optical depth increases near clouds due to factors such as the hygroscopic swelling of aerosols caused by the increased near-cloud humidity. The manuscript should discuss at least briefly–or perhaps using some calculations–whether cloud contamination or aerosol swelling (or even just the increased near-cloud humidity) could also play a role in the analyzed biases. If so, the findings should probably be reframed in the title and throughout the manuscript.

2.

Section 11 describes various attempts to improve the accuracy of bias-removal methods, but the authors conclude that none of the attempts proved successful in the end. Because the manuscript is already quite long, I suggest reducing the length of the section and limiting it to only a few sentences saying that the authors tried these approaches, but they did not prove helpful. Perhaps these sentences could even be merged into some other section The details of the unsuccessful attempts do not seem critical and my sense is that even Table 9 could be deleted. In general, the number and size of tables is quite large, and if the authors found ways to delete some other tables–or at least to move them into an appendix or supplemental material–this could make the paper more inviting to readers.

3.

It seems that the procedure described in Lines 625-627 should be affected by the random sampling noise that appears to cause some small-scale variability (local minima or maxima at certain Distkm-CSNoiseRatio bins) in Figure 12. If the bias correction were to be applied to a different dataset (which has its own different sampling noise),

this small-scale noise would presumably introduce additional errors into the correction. In addition to various nonlinearities, this sampling noise might also be a factor in why (as mentioned in Lines 638-640) linear regression is not performing as well as the bin-based process (Lines 625-627) for this dataset. I believe the manuscript should discuss the topic of sampling noise/variability somewhere.

Other issues:

Line 56: The word “ratio” should be added after “signal to noise”.

Line 155: It should be clarified where exactly the information contained in the CSU files comes from. Are these files created by combining selected data from operational MODIS productsâĂŤand if so, which ones?

Lines 159-160: Does it ever occur that the MODIS cloud product retrieves a cloud optical depth greater than 1.0 and yet the MODIS cloud mask does not say the pixel is cloudy? If yes, it would be interesting to discuss when and why this happens. If not, the word “or” may have to be replaced by “and”.

Line 263: It would help to clarify what happens if clouds occur inside the OCO-2 footprint.

Lines 283-284: For the benefit of readers not familiar with OCO-2, it would help to specify somewhere (in addition to the Crisp reference) what the OCO-2 pixel and footprint sizes are, what the difference is between the two, why 8 footprints are grouped together and how these footprints are arranged. Some of this is mentioned in Lines 298-299, but it would be helpful to see this (and the rest of the information) a bit earlier, right when first mentioned.

Lines 323-325: The wording should be refined to clarify whether land and ocean are combined or QF=0 and QF=1 are combined. In other words, whether the 40% is for QF=0 (land+ocean) and 73% is for QF=1 (land+ocean), or 40% is for land (QF=0 + QF=1) and 73% is for ocean (QF=0 + QF=1).

Table 2: It would help to clarify the used definition of seasons. For example, do summer statistics combine data from June-July-August over the Northern Hemisphere with data from December-January-February over the Southern Hemisphere?

Line 342: Shouldn't Figure 9 be moved to become Figure 2, just so readers don't need to jump from Figure 1 to Figure 9?

Line 349: It would help to specify what wavelength the monochromatic total optical depth is for.

Section 4: It would help to mention, if this is known, whether the key difference between the different 3D measures is that they consider standard deviation values over different spatial scales or at different wavelengths–or is it something else?

Figure 2 caption: The sentence "The sun is along the negative x axis" does not fit here; the x-axis shows optical depth, not any position or angle. The end portion of the caption also seems to refer to simulation setup and could be deleted, especially as the text mentions some of this info anyway (e.g., Line 382).

Lines 481-482: I recommend explaining why the 0.4 ppm bias at large distances from clouds can be attributed to 3D effects. This seems counter-intuitive, as this bias occurs in far-from-cloud cases where 3D effects should be weakest. Perhaps 3D effects that occur closer to clouds make the bias correction to be incorrect far from clouds? If the bias correction aims to remove overall biases (as mentioned in Lines 517-52), an overall correction that reduces biases near clouds could perhaps increase biases far from clouds at the same time?

Table 5 or other parts of Section 7: I wonder if the measures with the largest 3D biases are most suitable for capturing the key aspects of 3D effects, and measures with smaller biases are less so. In the extreme, an inept measure with no useful information about 3D effects would provide an estimate of zero for 3D effects. If this seems right, it may be worth mentioning in the paper.

Line 656: I guess it should be “5 and 10 km”, not “5 and 50 km”.

Line 765: The word “ocean” should be deleted.

Lines 777-778: It also seems potentially important and worth mentioning in the paper that clouds can move closer or farther as they drift with the wind during the 6 minutes between the OCO-2 and Aqua overpasses.

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