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Atmospheric Measurement Techniques Discussions

Interactive comment on "Quality controls, bias, and seasonality of CO_2 columns in the Boreal Forest with OCO-2, TCCON, and EM27/SUN measurements" *by* Nicole Jacobs et al.

Anonymous Referee #2

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This paper concerns an important problem encountered when using satellite-based observations to study the atmospheric component of the carbon cycle at high latitudes, namely the relative scarcity of satellite XCO2 data compared with that available over the mid-latitudes and the tropics. The difficulty in making ground-based observations in these regions, owing to harsh conditions and lack of accessibility and infrastructure, adds to the importance of satellite observations when studying the arctic region.

Jacobs et al. address this problem by considering the data quality filtering applied to OCO-2 data, noting that the quality filters applied as standard to the global dataset - with the goal of minimising bias and scatter compared with ground-based validation

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measurements made by TCCON sites around the world - may not be the most appropriate for a study focused purely on the Boreal regions. The goal, therefore, is to investigate whether certain quality filters and thresholds can be adjusted to increase the amount of quality filtered data over the Boreal region without significantly compromising the data quality.

In order to investigate the effect of introducing different quality filters on the bias and scatter, ground-based measurements are required to provide baseline XCO2 data to validate against. Data from two TCCON sites (East Trout Lake and Sodankyla) are used here, along with campaign measurements from two EM27/SUN instruments based in Fairbanks, Alaska. These instruments have become more established in satellite validation in recent years, and studies referred to in this paper have demonstrated that their performance is comparable to that of the TCCON stations. The EM27/SUNs are initially calibrated against the Caltech TCCON, and the same retrieval algorithm (GGG2014) is used on both TCCON and EM27/SUN throughout. This step is essential in that it allows the data from all three sites to be regarded as interchangeable, regardless of the instrument used at each site.

Jacobs et al. provide a detailed analysis of how their proposed quality control filter (Boreal QC) performs compared with two filters recommended by the OCO-2 science time (B8 QC and B9 QC), with great care taken to consider the impacts of specific thresholds on the filtered data. The increase in data throughput achievable whilst only introducing minor changes in average bias is an important outcome of this paper. They do however note that the biases exhibit some seasonal variability, mostly independent of the QC method used, which contribute to uncertainty in characterising seasonal cycles of carbon dioxide. It was interesting to see that it is the global bias correction itself that introduces the delta XCO2 seasonality seen in the Boreal data: I think this point could be made clearer by combining Figures 11 and 12 (for example, by plotting the bias-corrected and non-bias-corrected data on the same axes). An alternative bias correction (abc), taking into account the temperature dependence identified as

introducing the seasonality in the bias over the Boreal region, is derived and introduced for the B8 and B9 QC datasets, and shown to reduce (but not completely eliminate) the seasonality in the monthly average bias without affecting the monthly standard deviation.

The final part of the paper considers possible explanations for the differences in monthly average bias and standard deviation in bias between the Boreal and B9 QC filtered data, and looks at whether coincidence criteria or particular QC parameters that exhibit seasonal behaviour have a role in the seasonally dependent biases observed. Where it is concluded that a parameter is not likely to be a dominant source of seasonal variability in OCO-2 biases (proximity bias, ground-based instrument airmass dependence), I suggest moving these sub-sections to an appendix in order to make it more clear which parameters most urgently require further study.

Overall, this paper offers an in-depth consideration of how quality control filters applied globally to OCO-2 XCO2 data may not be the most appropriate for studying specific regions where the number of quality filtered data points becomes prohibitively low. The proposed Boreal QC filter is tested thoroughly in comparison with the B8 and B9 QC filters, and limitations with all three filters related to the seasonality in the XCO2 bias are identified and considered at length. A further outcome of this paper is that it demonstrates how, when supported by side-by-side pre-campaign calibration observations, the EM27/SUN and TCCON calibration data can be considered as equivalent (although the authors do rightly note that possible airmass dependence biases in the EM27/SUN data still require investigation). A final suggestion I have is that the Boreal QC filtered dataset could be made available in its own right, to allow for further study of the seasonality introduced by the bias correction.

I am happy to recommend this paper for publication, with the following suggested minor technical/organisational changes:

Pages 20/22: combine Figures 11 and 12 into a single figure, to emphasise how the

seasonality is introduced by the OCO-2 bias correction.

Pages 23/24/25: in Figures 15/16/17, for consistency with the text, I suggest using the label ‘abc’ instead of ‘bc’ when showing the ‘with T700’ results.

Sections 4.2 and 4.3: I suggest moving these (and their associated figures) to an appendix, so that the discussion section is more focused on the QC parameters which have a greater impact on the seasonal variability in the XCO2 biases.

Appendix A: a paragraph here which briefly describes how the quality control histograms are used to obtain the QC thresholds would be helpful (the authors may still refer to the O’Dell paper here for further detail).

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