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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Does GOSAT capture the true seasonal cycle of XCO_2?" *by* H. Lindqvist et al.

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Overview

This paper looks at the seasonal cycle amplitude from ACOS-GOSAT, 4 other GOSAT algorithms (RemoTeC, NIES, UoL, NIES-PPDF), and 3 models (CT2013B, UoE, Macc13.1) vs TCCON at 12 northern hemisphere TCCON sites and in latitude and longitudinal bins in the Northern Hemisphere. The seasonal cycle peak and minimum times, and secular increase are also investigated. The focus is on ACOS-GOSAT, and changes are explored for comparisons with ACOS-GOSAT such as different co-location schemes, aerosol treatment, and bias correction changes. The 5 other models and GOSAT algorithms are shown for comparison. The analysis finds a too-shallow sea-

sonal cycle for ACOS-GOSAT for European sites, but not in other GOSAT algorithms, and finds that when 2 components of the ACOS bias correction algorithm are removed, the seasonal cycle agreement improves but at the cost of larger single target errors. Other findings include that model-to-model variability in the seasonal cycle amplitude can be up to 2-3 ppm in regions poorly constrained by in situ data, e.g. (45N-50N,120-180E) or (0-25N). At the TCCON sites, the ACOS-GOSAT seasonal cycle error compared with TCCON is on the order of 1.0 ppm.

The paper is logically presented and well written; the content and presentation and quality are appropriate to ACP. The attributes that are studied are important for accurate flux estimates using GOSAT data, as errors will lead to systemic errors in flux estimates. Additionally, the comparison of the different GOSAT algorithms is very interesting as well as the large model-to-model variability in different parts of the world.

General comments:

The amplitude of the GOSAT fit should be viewed with caution above 60N where the gaps in the seasonal cycle could cause significant fit errors. When comparing to models, the same data gaps should be applied to both the models and the GOSAT and TCCON data.

The amplitude and phase of the fit may be partially prescribed by the fit function that is used, e.g. the fit of data far from the peak could affect the peak location and amplitude, so it is important to assess the fit minus data residuals for signal. The seasonal cycle peak and minimum might be more accurately calculated with a local smoothing function rather than a prescribed globally fit function. For this paper, plots and assessment of fit minus data residual signals, especially near the peak and minimum, and discussion of the above should be included if there are residual signals.

"As model-to-model differences in XCO2 can be several ppm at regions poorly sampled by insitu measurements, GOSAT observations that measure seasonal cycle amplitude to within 1.0 ppm, based on this study, could potentially be used directly (without elab-

orate inversions) to evaluate model differences at these regions."

The statement that GOSAT observations that measure seasonal cycle amplitude to within 1.0 ppm globally should be qualified. The satellite retrievals depend on a priori knowledge of the interferent species, like aerosols, temperature, and water, which will be better constrained in Europe and North America where most TCCON stations are. These errors may be larger in other parts of the world. The statement should be modified to something like "whereas the ACOS-GOSAT seasonal cycle error is on the order of 1.0 ppm near TCCON stations and likely to be of this size in other parts of the world, though may be influenced by the a priori accuracy of jointly retrieved parameters."

This should be updated in the text and conclusions.

Specific Comments:

Page 4 line 100: "likely to be affected by any seasonal biases present in the GOSAT/ACOS retrievals that are due to the ACOS system itself." change to "likely to be affected by any seasonal biases present in the GOSAT/ACOS retrievals that are due to the ACOS system or ACOS a priori inputs."

Page 5, line 130 "Their validated and calibrated higher precision and accuracy compared to satellite observations, coupled with the fact that they measure the same quantity in essentially the same way as the satellites" change to " coupled with the fact that they measure the same quantity in essentially the same way as the satellites, though looking directly at the sun rather than sunlight reflected off the earth, so are not affected by surface albedo, "

Page 5, line 145. The southern hemisphere amplitude is small, however it is has large flux uncertainties and less in situ data, so that satellites could add significant guidance to models. I would not discount it but rather state why your analysis is not appropriate for it or that you choose to focus on the northern hemisphere.

Page 5, line 190. It doesn't seem like TCCON should be hyphenated at a line break

e.g. TC-CON.

Page 7, line 219, "Finally, we calculated daily averages of both GOSAT/ACOS and TCCON retrievals." What is the local time of TCCON that is averaged? Is it the time averaged for TCCON around the time of the GOSAT observations? Please state.

Page 8, line 235. The "daily error" for GOSAT/ACOS and TCCON are of interest, so state what they are.

Page 8, line 235. The fit chosen may also not be the correct seasonal fit, so it is important to note whether the TCCON error (in particular since TCCON errors are smaller) is randomly distributed about the fit. This can be shown with a difference plot, e.g. with green dots around the dashed lines in figure 4, or in a separate figure, in particular for a case where there are larger differences in the maximum location.

Page 8, Equation 1. cos-1() has a domain issue in that cos-1(x) will range from 0 to pi, rather than -pi to pi. I can't quite wrap my mind around what sin(cos-1(acos(wt))) does. Could you give the fit values for a0-a5 for at least one example, e.g. Park Falls. I assume that the cos-1() term is to give a time-dependent phase. Is this a standard equation for fitting a seasonal cycle? Is there a reference for this fit? It doesn't matter if there is a reference if it does a good job; the quality of the fit should be assessed by looking at residuals of fit-data (see general comments).

Page 9, Line 286, "The satellite observes the maximum later than the TCCON at the European sites, but obtains good agreement elsewhere. At the European sites, the difference extends up to 2–3 weeks, and is likely connected with the biased amplitude inferred by ACOS discussed below." Fitting can create phase differences if the fitting function does not match the data shape (see general comments). Can a plot be shown of the GOSAT/ACOS and TCCON data for a station where there is a phase difference between TCCON and GOSAT so that the reader can see that the data supports the fit shape? Kulawik et al., 2015 used cross-correlation to determine phase shift and found a much smaller phase difference in Europe, which seems in disagreement of

your findings.

Page 12, line 390, " These results can be interpreted to support the ensemble median algorithm EMMA introduced by Reuter et al. (2013), which combines all individual retrievals into one data set that globally has the best agreement with TCCON." It would be useful to add EMMA to Figure 6.

Page 12, line 405, " The seasonal cycle was fitted on the daily averages of GOSAT/ACOS XCO2 and the resampled models." The models were presumably sampled in the daytime? It is important to match the approximate GOSAT overpass time. Also, see general comments, gaps in the GOSAT data can result in differences from a complete seasonal cycle.

Page 13, line 427, "From 60_ to 70_, ACOS has a higher seasonal cycle amplitude than most models." North of 60N the gaps in GOSAT seasonal data are such that the peak fit of the seasonal cycle is likely outside of the seasonal span of GOSAT data, see general comments. To compare to model fits, both models and data should have the same data gaps.

Page 13, line 440, that the averaging kernel correction results in a modest systematic effect on the seasonal cycle amplitude is an important finding which should be mentioned in the conclusions. A seasonally dependent 0.2 ppm error could have a significant impact on flux estimates.

Page 15, line 508. Accuracy of GOSAT/ACOS results has dependence on prior information of the interferents and some caution is a warranted regarding the accuracy far from TCCON sites.

Figure 2. The tan background makes the colors hard to see.

Figure 5 label: Refer to Panel (a) and Panel (b) rather than Panel a and Panel b.

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